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RESEARCHES ON THE FISHERIES GROUNDS IN RELATION TO THE SCATTERING LAYER OF SUPERSONIC WAVE [INTRODUCTORY REPORT]

Michitaka UDA*

(Received Jan. 25, 1956)

Introduction

The world-wide wonderful phenomenon in the submarine waters named DSL (Deep Scattering Layer), which was first discovered by 3 American physists (C. EYRING, R. CHRISTIENSEN, R. RAITT)[1] in the Scripps Institution of Oceanography in U.S.A and afterwards suggested by MARTIN JOHNSON (marine biologist)[2] as a

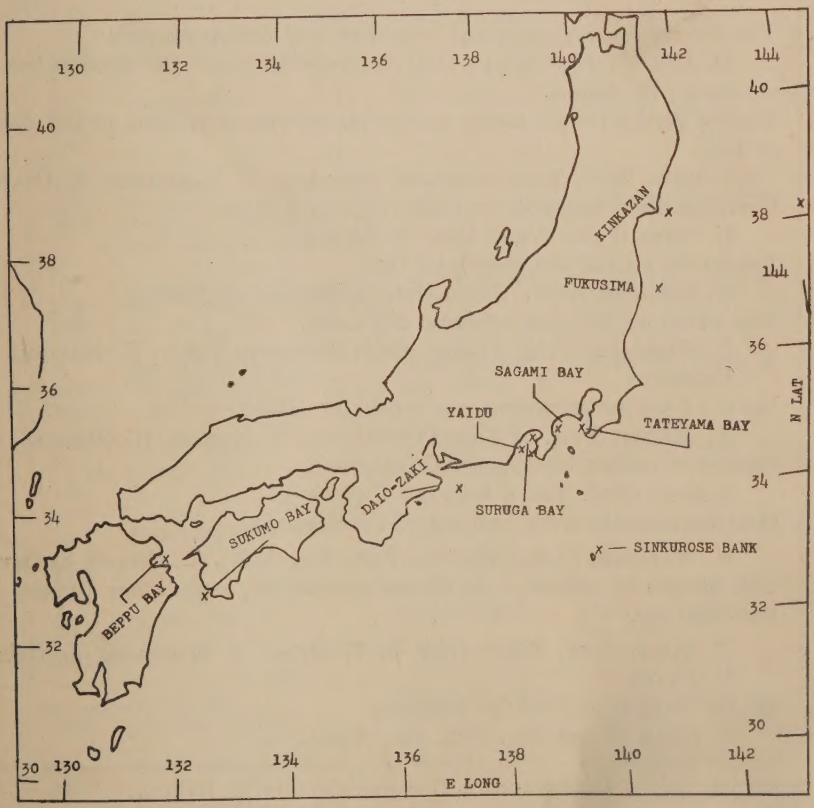

Fig. 1. General Map Showing the Locations of DSL Surveyed (× mark).

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concentrated layer of macroplankton groups due to the vertical diurnal migration.

Since then a series of researches on DSL was followed by the marine scientists in many countries as an up-to-date problem of modern oceanography and reported the world-wide occurrence in seas and oceans including the antarctic ocean and have discussed these phenomena formerly so-called as "ghost", "phantom bottom", "false bottom", "plankton bottom" etc. as the concentrated layer of zooplanktons, or deep sea fishes (inclusive squids) or both with active discussions. (Refer to literatures quoted in this paper.)[1-31]

In Japan the first supersonic wave type fish-finder (piezoelectric pattern of 200 KC) constructed and experimented with success in 1929 by K. KIMURA[29] under the supervision of Prof. Dr. M. TAUTI in the Imperial Fisheries Inst. and again

Table I. DSL Research Project (with Research members).

No.	Terms
1.	The synthetic oceanographical conditions and fishing grounds. M. UDA (Prof. of Tokyo Univ. of Fisheries) with the collabolators Y. SAITŌ, M. ISHINO.
2.	Fishing survey on the useful marine inhabitants in relation to the nature of DSL. J. IHARA (Prof. Tokyo Univ. of Fisheries), Y. YAMAGUCHI, K. OZAWA.
3.	Oceanographic researches in relation to sea bottom. H. NIINO (Prof. Tokyo Univ. Fisheries).
4.	Researches on the fish-finder and DSL. T. KUMAGORI (Prof. Tokyo Univ. Fisheries), H. SUZUKI.
5.	Researches on the most effective fish-finder. T. HASHIMOTO (The Fishing Craft Research Inst.), Y. MANIWA, M. NISHIMURA.
6.	Study of marine organisms and waters in relation to DSL. Y. MATSUE (Prof. of Tokyo University), Y. KOMAKI, H. NAGAYA.
7.	Studies of marine inhabitants (Crustacean). I. KUBO (Prof. Tokyo Univ. of Fisheries),
8.	Oceanographical survey and analysis of seawater. N. WATANABE (Tokai Regional Fish. Res. Inst.), T. HIRANO, K. ŌKUBO.
9.	DSL Studies by means of submarine photometer, underwater camera and television etc. T. SASAKI (Prof. Tokyo Univ. of Fisheries), S. WATANABE, G. ŌSHIBA, N. OKAMI.
10.	On the Method of Plankton Sampling. Z. NAKAI (Tokai Reg. Fish. Res. Inst.).

Research Boats Used	Umitaka-maru	(755 ton) Captain K. HARADA
	Shinyō-maru	(236 ton) Captain M. NAGAYAMA
	Seichō-maru	(62 ton) Captain K. NARUSE
	Sitigō-tei	(15 ton) Captain ≈. MANDOKORO

in 1942 a new type fish-finder constructed of magnetostriction pattern by K. Miyoshi and T. Miyazaki in the same laboratory[30].

In 1941 a curious layer called "N" layer was found by the Japanese naval experts (Mr. Hashimoto and others)[31], which in fact corresponds to DSL at present. After the World War II (about 1949) the fish-finders of various pattern submitted to general use through industrial mass production. In 1952 we organized a research group for DSL in relation to fishing grounds under the aids of the scientific research grant supplied by the Ministry of Education, which has the purpose to study the nature of DSL and to find the relation between the swarming, dispersal, movement of fishes etc. and DSL, and to obtain a effective method to evaluate the productivity of the sea, fishing grounds and fishing conditions unfavourable or favourable. Its project and research members are tabulated in the Table I, and the list of our surveys are shown in the following Table II.

Table II. List of the Main DSL Survey (Refer to Fig. 1).

No.	Period	Seas surveyed	Research Vessel	Purpose to study
1.	VIII 19–29 1952	Kumano-Nada, Zunan-Sea-region, NE. Sea of Japan (Yokkaiti-Onagawa)	Umitaka-maru	General searching of DSL in pelagic fishing grounds.
2.	IX 10–15 1952	Suruga Bay	Seichō-maru	DSL in Sergestes-shrimp fiishing ground
3.	XII 2–13 1952	Suō-Nada, Beppu Bay, Bungosuidō, Tosa Bay, Kiisuidō, Ensyūnada, Sagami Bay. (Simonoseki-Ito)	Umitaka-maru	Squid and sardine fishing grounds in the Bays
4.	II 6–20 1953	Zunan-Sea-region, Sagami Bay, Suruga Bay, Gaibō Adj. Sea.	Umitaka-maru	Mackerel, horse-mackerel, yellow-tail and Sergestes-shrimp fishing ground
5.	X 24–26 1953	Out of Tokyo Bay, Tateyama Bay	Seichō-maru No. 7-Boat	Mackerel fishing ground
6.	III 12–19 1954	Sagami Bay, Suruga Bay	Seichō-maru	Yellow-tail and Sergestes-shrimp fishing grounds
7.	X 16–20 1954	Tateyama Bay	Seichō-maru	Mackerel fishing ground
8.	III 14–20 1955	Suruga Bay	Seichō-maru	Sergestes-shrimp fishing ground
1′.	summer 1953	Bering Sea, Aleutian Waters	Umitaka-maru	Alaska pollack, salmon grounds
2′.	summer 1954	Western Pacific Ocean	Umitaka-maru	Tuna ground
3′.	winter 1954	Zunan-Sea-region, Hyōtan Bank	Shinyō-maru	Mackerel and horse-mackerel grounds

Results

In the following the author wishes to report on the general results on behalf of the DSL Research Group[32].

(1) By our survey in the adjacent waters of Japan the scattering layers were found broadly throughout the sea-regions of inland sea, coastal waters, in bays, gulfs and offings, such as in the Kurosiwo current-area and Oyasiwo current-area (off Kinkazan), and found throughout the seasons (summer, autumn and winter) in the year. In summer we found DSL in the offiing and near shore, but in winter only conspicuous appearance in the coastal water region, and scanty in the open ocean.

(2) The frequent and dense occurrence of DSL corresponds to the regions near the shelf edge (or in the vicinity of fish-bank) which indicates the steep increase of the bottom slope and conspicuous upwelling there.

In general we can say the frequent and dense localities of DSL coincides with the favourable fishing grounds and we can see the assemblage of many fishing boats and the favourable fishing conditions there, for example, in Dec. 1952 in the Beppu Bay the squid fishing-ground, in Tateyama Bay in the autumn mackerel fishing-ground, in winter the yellow-tail fishing-ground in the Sagami Bay and the Sergestes-shrimp fishing grounds in the Suruga Bay. Also the frequent occurrence of DSL at the front of water masses (e.g. a zone of convergence off Kinkazan where the cold and warm current meet together).

Along our coast the region of the steepest slope near the shelf edge we have observed a cospicuous upwelling together with DSL, especially during the seasons of autumn and winter the north-westerly monsoon prevailing at the head of the sea valley (the portion of the maximum curvature of the 200 m. isobath contour) upwelling most developed localities, a very conspicuous DSL trace corresponding to the favourable coastal fishing ground. The regions around fishing banks indicating the developed topographical upwelling in particular on the rear and front portion of banks, show also the frequent occurrence of DSL. For example Hyōtan-Se and Kinsu correspond to the mackerel and horse mackerel fishing grounds, and Shinkurose the skipjack fishing ground. The current boundary of cold and warm currents (front) off Kinkazan has shown DSL which indicates frequently the skipjack and whale fishing grounds.

DSL occurs also frequently near the coastal front between oceanic and neritic water which corresponds to the coastal fishing grounds such as sardine, anchovy, mackerel, horse mackerel, squid and yellow-tail fishing grounds. Moreover, we can find DSL in the core portion of eddies (especially of cyclonic eddies) where the favourable fishing grounds produced, and perhaps due to some accumulated scatterers such as plankton-swarms.

(3) The typical DSL shows the phenomena of morning descent and evening ascent in the dawn and dusk (at the time of twilight) near the moments after sun-set and before sunrise can explain the dense swarming of fishes and the most active feeding of fishes. Now we can agree the above to the generally accepted experiences of fishermen.

Sergestes-shrimps begin to ascend just when sun sets down and arrive at

the top-layer at the beginning of the darkness of night (at the end of the astronomical twilight).

By means of SASAKI's Submarine Photometer the diurnal ascent and descent of DSL (vertical migration following the surface of some definite iso-submarine illumination, in other words the echo-trace of DSL corresponding to the vertical migration of some concentrated living organisms as the scatterers of supersonic waves.

In spite of our incomplete sampling of the living organisms of DSL, we can prove the substancial scatterers in this case as the macro-zooplankton groupes mingled by the small-size fishes and shrimps showing all compound band-like echo-trace (for those animals attracted by light i.e. due to phototaxis). Here we can infer the mechanism constituting a fishing ground.

The vertical migration with the velocity of 1–8 cm./s. or 0.6–5 m/min. and also the ascending speed less than the descending one (e.g. in some cases the ascending speed after sun-set of the order 1 cm./s. and the descending one before sun-rise of the order 2 cm./s.) Accordingly the average velocity 4–5 cm./s. (2–3 m./min.) corresponds to the locomotive migrating velocity of the scatterer plankton in DSL conceivably.

DSL daytime descends to the level of the depth 300–400 m. perhaps defined by the optimum submarine illumination and water temperature with thermocline and settles there. (For example at the station 20 SM south off Daiō-zaki of Kumano Nada, bottom depth 1000 m. we found DSL at the level of 410 m. depth, and also in Suruga Bay DSL off Yaizu at the level 324 m. depth in that case the bottom depth 380 m. Sometimes DSL changes its echo-trace pattern such as curtain-like or laminar, spotty and turbulent alike to some bushes subjecting to the state of aggregation or movement of scatterers including fishes. The thickness of DSL varies from 10 m. to 150 m., sometimes representing double or triple, multiple stratified layers of DSL, and suggesting seemingly the concentration of different sorts of scattering organisms. J. B. HERSEY, H. R. JOHNSON, L. C. DAVIS (1952) have reported on DSL of different characteristic echo-trace due to the accumulated various kinds of scattering elements by means of the echo sounders having frequencies of 2–19 KC at some time interval, and at some localities, and at some depths.

The variation of submarine illumination due to the moon light and cloudiness reflects sensibly to the state of DSL and causes its temporary descent or ascent and diffusion or vanishment of DSL trace. The diffusion of DSL echo-trace (perhaps indicating the dispersal of food animals) may interprete the reason of bad fishing in the period of moon light for the fisheries of Sergestes-shrimp, squid, sardine, mackerel, pacific saury etc. using the method of attraction (lure) by fishlamp. In summer season of 1953 in the Bering Sea on board of Umitaka Maru the echo-traces of DSL associated with salmon and alaska pollack schools were observed, which migrating up and down with the variation of concentration in accompany with the variation of the moon illumination during the full moon period of 13–18 moon-age nights i.e. with the higher altitude of full moon DSL descends to the lower and shows the broader diffused layer corresponding to the dispersal of the scatterers.

In general the diurnally migrating DSL of mainly composed by macro-plankton groupes seems to contribute to the formation of the favourable fishing grounds. We can infer that DSL of this sorts may be well associated with the fishing grounds. However we could not recognize DSL by the concentrated layer of phyto-plankton such as diatoms in spite of remarkable abundance for example showing brownish color of the sea water in Sagami-Bay in February 1953 and Beppu Bay in December of 1952.

(4) The appearance of DSL for the acoustical range of frequencies 14, 24, 50, 100, 200 KC was ascertained by the remarkable difference of the trace pattern as laminar or massive structure due to probably the size of the scatterers and the ecological state of its swarming. We can expect a newly designed DSL proper recording fish-finder by means of supersonic wave in near future commercially as the result of development by Messrs. Hashimoto and Maniwa and may get the characteristic features of DSL pattern for the indicators of Sergestes-shrimp, sardine, anchovy, yellow-tail and alaska pollack fishing grounds etc. It may become a new useful oceanographic tool to exploit new fishing grounds including pelagic fishes and trawl fishes.

(5) The echo-trace of our oceanographic instruments suspended in the submarine water can be detected down to the depth of 200 m. and abled us easily to ob-

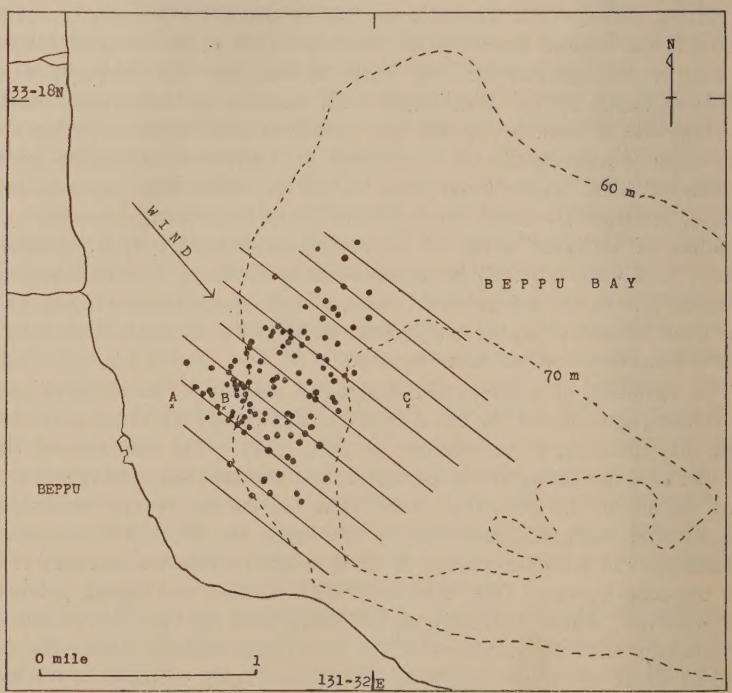

Fig. 2-a. Fishing Ground and DSL Surveyed in Buppu Bay. (× mark—Station Surveyed, black circle—Squid Fishing Boat, hachure area—DSL.)

serve and to sample in the DSL layer as we will, with the accuracy to detect the falling noise of messenger on the water bottle, plankton net or water surface. When the nets or other equipments hauled and suspended in DSL we can observe the DSL descending and diffusing temporarily (e.g. in the yellow-tail fishing ground in the Sagami Bay).

(6) Dr. Sasaki and others constructed a new type of self-recording submarine thermometer of thermister type having the accuracy of 10^{-2}°C down to the depth of 360 m., a newly designed submarine photometer having the accuracy of 10^{-6} lux and a new useful underwater camera and applied all the above to our DSL research. The law of exponential decay concerning on the submarine illumination and the deviation of it due to the light scattering in DSL, thermocline etc. were found particularly.

(7) The experiment on the board of our boat has shown the echo-trace by means of sand particles thrown in the sea below to the depth of several ten meters. In the innermost shore water of Suruga Bay we have found the striped pattern echo-trace due to the fiberous turbid scatterers in the bottom water which discharged from the estuaries by the pulp-mill factories where indicates brownish water pollution with bad smell.

On board of Umitaka Maru in Isikari Bay K. Ozawa remarked a DSL of nonstationary type due to probably the turbid mud particles discharged from Isikari River with snow-melted water and suspended along the pycnocline layer.

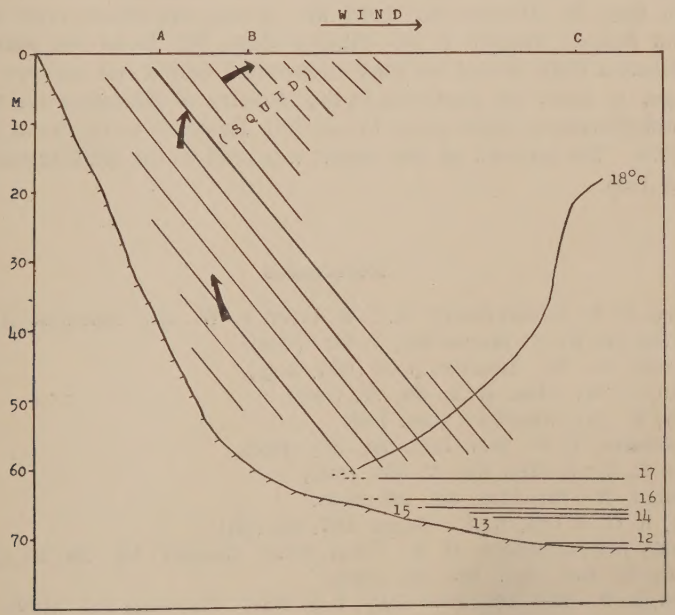

Fig. 2-b. The Distribution of Temp. and DSL in the Sectional Chart. (arrow—Direction of Upwelling, hachure area—DSL.)

He found herring shoals migrating only in the layer above the pycnocline in that season.

(8) In the central core region of eddies (whirls) we see frequently DSL (e.g. "Ōsaki-Dasi" bank off Itō where squids, horse mackerel, bonito etc. swarms). In the Uwazima Bay we observed the same DSL in the sardine fishing ground due to perhaps the accumulated scatterers in the eddies.

(9) In Dec. 1952 on board of Umitaka Maru we observed in the central concave basin of Beppu Bay having the bottom depth of 70–75 m. and found a stagnated cold bottom water (10°C), poor in dissolved oxygen, the upper homothermal water (about 14°C) above the depth of 60 m., and near at the level of 60 m. depth a discontinuity layer (thermocline or pycnocline) in neighbouring DSL layer, perhaps due to the accumulation of scatterers including planktons and suspended turbid matters. (See fig. 2 a, b). The northwestern steep slope of the basin some prosperous upwelling by the strong north west monsoon and the corresponding dense DSL in the range of water temperature of 10°–20°C where several tens fishing boats operating active squid fishing were observed.

Acknowledgement

In concluding this report the author wishes to state of his heartiful thanks as the representative of our DSL Research Group to the Ōita Prefectural Fisheries Experimental St. (Director and Mr. NŌDU, crew of Hayasui-Maru), the Siduoka Pref. Fish. Expt. St. (Director Mr. ANDŌ, Mr. SEKINO and others, crew of Asitaka-Maru), its Branch Station at Itō (Hasima-Maru, Mr. INABA and others), to the Yaidu Fisheries High School for their cooperation during our surveys. Also we are obliged to state our gratitude to the Ministry of Education for the aids by the Scientific Research Grant given to our DSL Research in the fiscal years from 1952 to 1954. The abstract of this report was read at the IPFC Meeting (Tokyo) in Oct. of 1955.

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STUDY OF DSL BY ULTRASONIC WAVE (1)

Tomiju Hashimoto and Yoshinobu Maniwa*

(Received Jan. 25, 1956)

1. Introduction

When the ultrasonic wave propagates vertically in the sea water, sometimes, its echo shows Deep Scattering Layer. Already in 1940, one of the writers (Hashimoto) found it and named it 'N Layer,' off Nojima Cape, showing the steep temperature gradient at about 500 meters in depth and the conspicuous variation of the acoustic impedance, with shoaling fishes and plankton at such a locality[1].

Since that period, the study of DSL has begun in several countries. The frequencies of the ultrasonic wave used for it ranges from about 10 kc to 50 kc.

In order to make clear the relation between DSL and fishery mainly in the adjacent seas of Japan, in the western Pacific Ocean, Beppu Bay, Tateyama Bay, Suruga Bay and Sagami Bay, the writers studied of the actual states of DSL in combination with oceanographical observations, measured the reflection loss of the ultrasonic wave on it, and referred to the effect by the difference of frequency.

2. Observations of DSL in Beppu Bay, etc.

From Yokkaichi to Kinkazan via Hachijo Island, in August 1952, on the Inland sea and on the coast of the southern part of Japan in December in the same year, in Suruga Bay and Sagami Bay in February 1953, the writers observed DSL by means of the echo-sounder of ultrasonic wave type (frequencies of 14.5 and 24 kc) and obtained results successfully as shown in p. 169~171.

(1) In the adjacent seas of Japan, DSL was found in the Inland Sea, in the open seas, in bays and in the regions of Kuroshio Current and Oyashio Current off Kinkazan in Summer and Winter. In Summer, it was found in the coastal waters and also in the open sea, but in winter prevalently in the coastal waters.

(2) DSL appeared especially at the localities where the slope of the sea-bottom increased near the shelf-edge, and near the fishing banks, (such as the Shinkurose Bank), and also at the boundary of currents (such as the offing one of Kinkazan), and moreover, seemingly it appeared at the localities of the complicatedly varied bottom configuration related to the favourable fishing grounds.

(3) The depth of DSL observed was at the 10 meters to 410 meters level.

(4) The echotrace (record) of DSL continued uniformly as a band and showed one or several layers, having different thickness by the locality and time.

(5) DSL appeared so often especially at twilight before and after sunrise

* Fishing Boat Laboratory.

and sunset, and frequently in night following to dusk but obscure. DSL ascended about at sunset and descended before sunrise.

(6) We are not sure whether some concentration of scatterers at DSL consisted especially of abundance of large sized zooplankton.

(7) Fig. 1 and 2 show some instances showing the temperature and density distributions of sea-water at the localities of DSL. There were some cases of DSL in relation to thermocline and in consequence probably to the distribution of scatterers. In our case, DSL lies in the range of water temperature of 10°C to 20°C. It was not found at all in the stagnated cold water, oxygen very poorly dissolved, at the bottom of Beppu Bay, and appeared distinctly above it, or in other word, above the thermocline (see Fig. 3). Fig. 4 shows the record of DSL at the locality, 13.5 miles off Kinkazan. Fig. 5 is the echotrace in Beppu Bay in which DSL appeared at sunset and disappeared at sunrise.

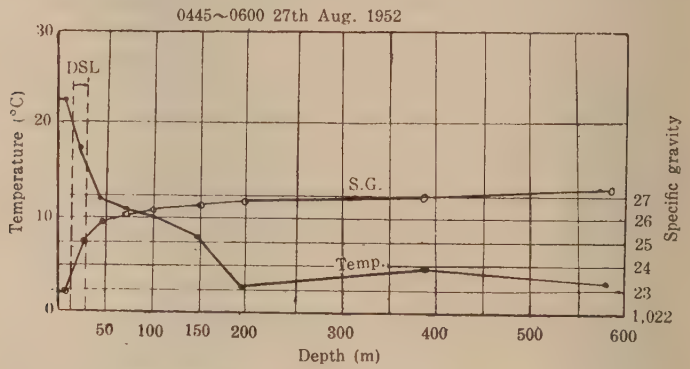


Fig. 1. Vertical distribution of water temparature and specific gravity. (st. 22, 140 sea-miles E. off Kinkazan.)

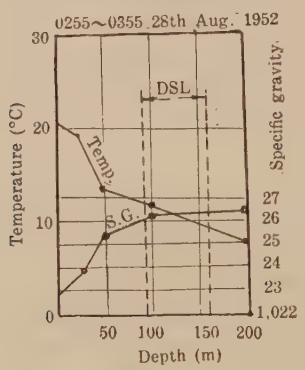


Fig. 2, Vertical distribution of water temperature and specific gravity. (st. 27, 13.5 sea-miles E. off Kinkazan.)

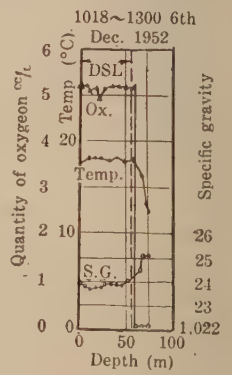


Fig. 3. Vertical distribution of water temperature and specific gravity and quantity of oxygeon of sea-water. (Beppu Bay)

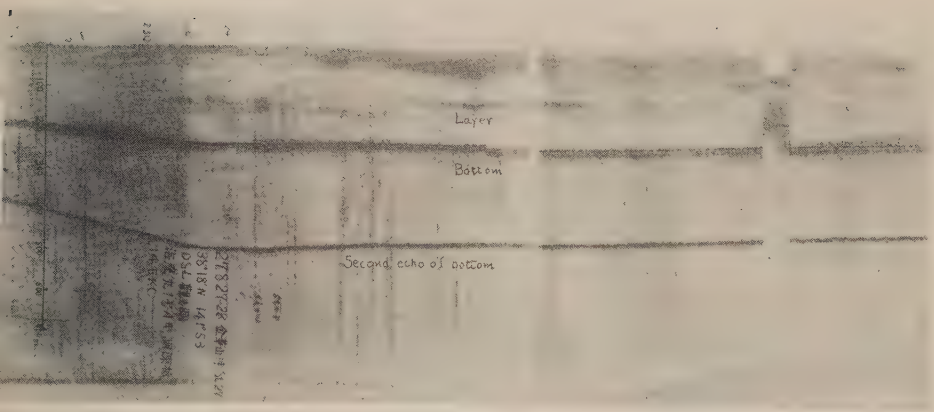


Fig. 4. Record by means of frequency of 14.5 kc corresponding to Fig. 2.

3. Observation in Suruga Bay and Sagami Bay

During 12th to 18th March 1954, the writers observed DSL on the board of Seichomaru of the Tokyo University of Fisheries, at the fishing ground of Sergestes-shrimp (Sakura Ebi, *Sergestes prehensilis*) off Yaizu in Suruga Bay and of yellowtail off Ito and Ajiro in Sagami Bay. During our observation the ship stayed, but owing to the driftage by the current, the shape of the sea-bottom varied as if the ship was running. The stations are shown in Fig. 6. The frequency of echo-sounder used in observation was 24 kc.

(1) Observation at Fishing Ground of Sergestes Shrimp (Sakura Ebi, Sergestes prehensilis) off Yaizu in Suruga Bay.

In order to make clear DSL at the fishing ground of Sergestes-shrimp, observation was made, off Yaizu in the evening on 13th and 14th March in its fishing season.

(1–1) Characteristics of Form of DSL

This station located at the steep slope of sea-bottom off Yaizu where the isobathymetric lines of 200 meters to 800 meters run closely near the coast and a type of pocket basin was formed. The bottom depths of the stations were 80 meters to 350 meters, showing complicated features of rise and fall and mainly muddy sediments.

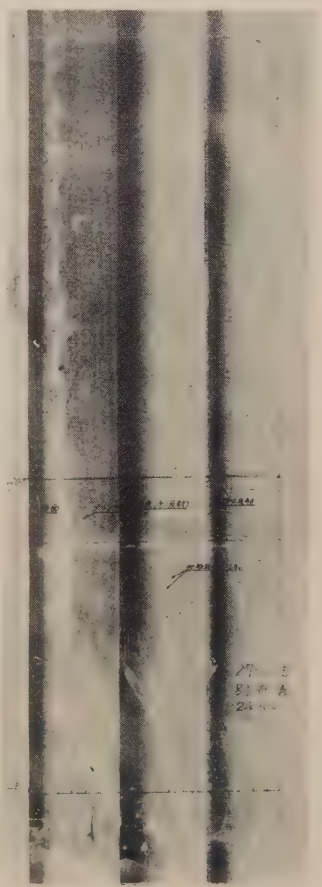


Fig. 5. Record by means of frequency of 24 kc. corresponding to Fig. 3 in Beppu Bay.

Fig. 7. shows the observed record of echotrace (A, B,....DSL). In it, from about 1700 before sunset, DSL appeared thinly at 50 meters to 70 meters in depth, continued in that state, and beginning to ascend gradually

Fig. 6. Observing station of DSL.

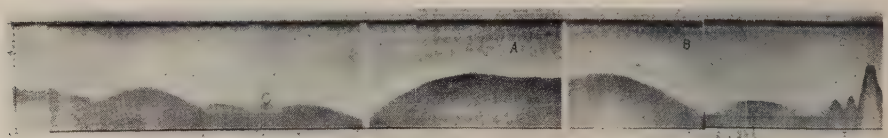


Fig. 7. Record at fishing ground of Sergestes-shrimp off Yaizu.

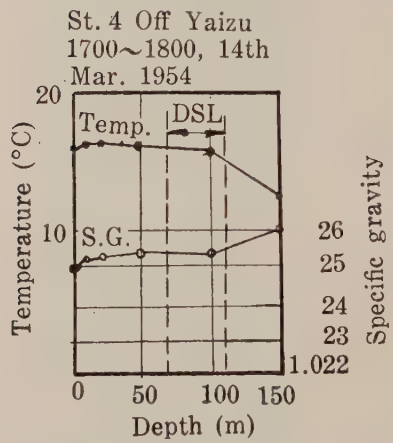


Fig. 8. Vertical distribution of water temperature and specific gravity, corresponding to Fig. 7.

at 1750 of sunset, at last formed one thick layer at the depth of about 10 meters to 20 meters, and then continued somewhat in diffusing state until about 2000. From the time 2000, the thickness of the layer became about 40 meters, and then separating into 2 or several layers, descended gradually. Of course, these states are more or less different by day. The thickness of these layers did not changed suddenly, but their upper and lower edges were obscure.

Fig. 8. shows the vertical distribution of water temperature at the measuring station of DSL corresponding steeper temperature gradient.

(1-2) Results of Observation

In our neighbourhood, about 50 sets of Sergestes-shrimp fishing boat worked from

sunset with catch per boat about 260 kg to 750 kg in an average.

We sampled Sergestes-shrimps by the specially designed hauling net at these layers in several times, and each obtained several to twenty individuals of Sergestes-shrimps, mingled with Togari Salpa (or "Tanekurage" called by fishermen, Salpa fusiformis). Also Sergestes-shrimp was caught once by a plankton net at the scattering layer. By using plankton net, abundance of zooplankton, such as Copepoda, etc. and Salpa fusiformis, was collected at the depth of the scattering layer more than at the other depth. The measured distribution of water temperature and density at this station are shown in Fig. 8, including the depth of DSL. The temperature of this depth is in optimum for Sergestes-shrimp, i.e. 15°C–16°C. In conclusion a remarkable amount of Sergestes-shrimp, Salpa and zooplankton, Copepoda and so on, gathered at DSL at this fishing ground was found.

(2) Observation at Ajiro Fishing Ground of Yellowtail.

Observation was made in the evening of 17th (the lunar age was 13th and sun set at 1809) March, at the station where the bottom rised steeply from the depth of 200 meters to the depth of 100 meters and the comparatively high transparency of sea water was 14 meters. The yellowtail fishing ground lies near the shelf-edge.

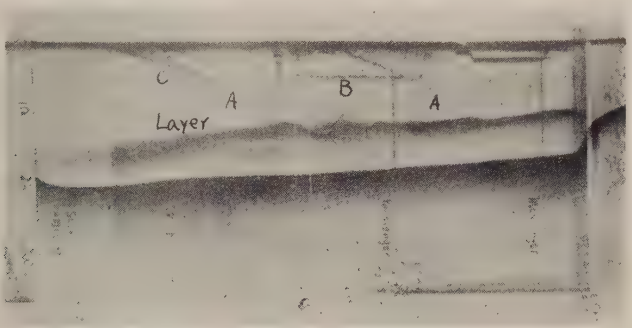


Fig. 9. Record at yellowtail fishing ground of Ajiro.
A: Photometer B: Water bottle C: Plankton net

(2–1) Characteristics of Form of DSL.

Fig. 9 shows the observed record of DSL. At 1709, at the ascent as mentioned above, a dark DSL-trace with a peculiar form appeared at the depth of 150 meters to 180 meters, while we wondering false bottom or not. Meanwhile the depth of the sea-bottom varying gradually, this upper edge of DSL continued in height of 60 meters to 70 meters almost parallel with the sea bottom, and in the beginning, its thickness was 30 meters and its lower edge was in

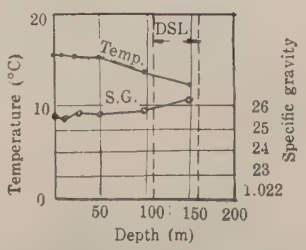


Fig. 10. Vertical distribution of water temperature and specific gravity, corresponding to Fig. 9.

contact with the bottom, then its lower edge ascending gradually, its thickness decreased to about 20 meters and the reflection loss on it became little. There was a fish shoal trace about it in the echogram.

From 1750, several thin layers appeared at the depth of 20 meters to 40 meters, over the shelf-edge at 80 meters in depth. From 1800 the fish shoal trace were found here and there at the depth of 40 meters to 70 meters, which corresponds to the depth of the migration layer of yellowtail.

Soon, it changed into many thin layers from the surface to the bottom. (See Fig. 11.)

(2–2) Results of Observation

The vertical distribution of water temperature and density on the shelf-edge are shown in Fig. 10, showing no remarkable gradient, at the depth of DSL. At this station, a plenty of Diatom and zooplankton, such as Copepoda and Gammalus etc., were collected.

As every instrument of observation was let down just beside the transducer while the current was very slow and the inclination of the wire was less than several degrees, they were clearly recorded as shown in Fig. 9 and Fig. 11 and its true gauge depth agreed well with the depth in the record, therefore observation was made precisely at the required depth. When the messenger struck the sea-surface and the water bottle at each depth of observation, echoes were recorded on the recording paper and those moments agreed with the times when shocks were felt on the wire, and even when no shock was felt, the signs of the messenger striking on the water bottle were marked in the record. The similar phenomena was seen for the plankton net.

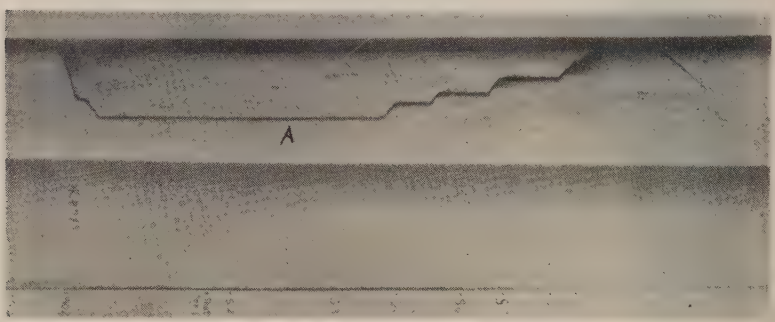


Fig. 11. Record considered as shoal of yellowtail
C: Underwater camera

(3) Observation at Ajiro Fishing Ground of Yellowtail.

Observation was made in the early morning on 18th of March at the station in the neighbourhood of the shelf-edge where the bottom rises from the depth about 300 meters to 100 meters.

(3–1) Characteristics of DSL

Fig. 12 is the observed echo-trace of DSL. At 0430, several DSL

appeared on the shelf-edge at 50 meters to 150 meters in depth, and they continued until 0515, increasing its margin of reflection, with shoals of fish appearing in neighbouring zone, and a layer of the thickness of 10 meters descended rapidly from about 0520 to sunrise (0609), and then disappeared.

(3–2) Results of Observation

The distribution of temperature is shown in Fig. 13. Plankton was consisted of a big amount of Diatom.

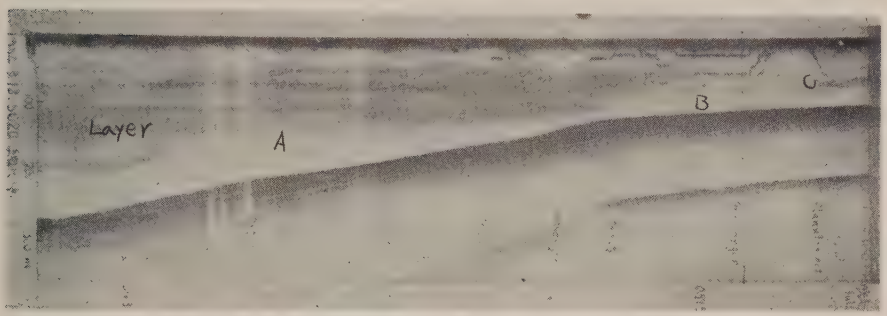


Fig. 12. Record at yellowtail fishing ground off Ajiro.
A: Electric recording thermometer B: Water bottle C: Plankton net

(4) Observation at Kawana Fishing Ground of Yellowtail.

The observation was made in the evening on 18th March. The observing station was in the neighbourhood of the shelf-edge zone where the bottom rises steeply from about 150 meters to 50 meters in depth.

(4–1) Characteristics of DSL.

Fig. 14 shows the observed record of DSL. In this record, at 1610, DSL appeared on the bottom of the depth of 150 meters, with its lower edge lying nearly horizontally and its upper edge forming like mountains, its thickness ranges from 40 meters to 10 meters, and after ascending gradually parallel to the bottom, it reached to the surface about at sunset (1809), and then the echo-trace representing shoals of fish appeared. This scattering layer was very similar to that at the shelf-edge already explained in (2).

(4–2) Results of Observation.

The vertical distribution of water temperature in Fig. 15 shows its slight

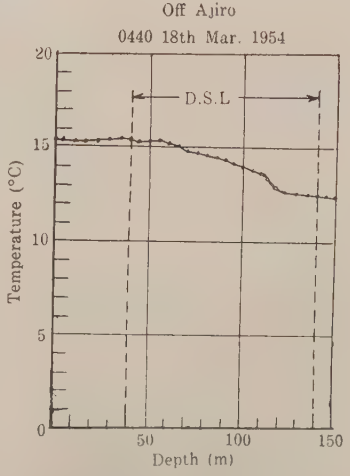


Fig. 13. Vertical distribution of water temperature and specific gravity, corresponding to Fig. 12.

variation. The vertical distribution of submarine illumination in water measured by a new designed photometer, is shown in Fig. 16*. In this case, whether the window of the photo-cell faces upwards or downwards, the attenuation curve of submarine illumination in water deviates from the commonly established exponential function at the depth of DSL, probably caused by scattered light by scatterers at DSL, where plankton constituted mainly by Diatom found more at DSL than at other levels.

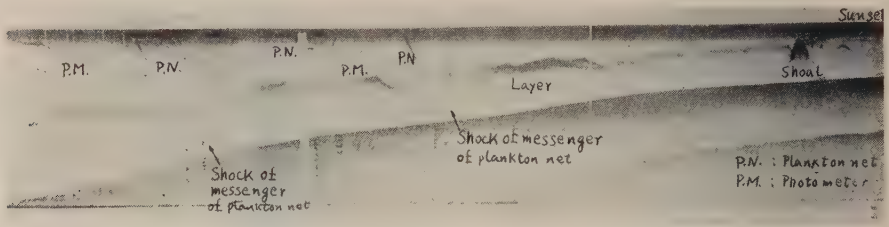


Fig. 14. Record at fishing ground of yellowtail off Kawana. Significant data in which plankton net is hung precisely at DSL.

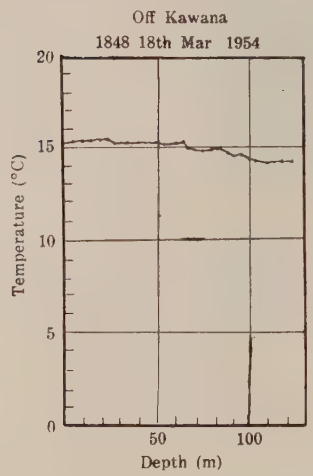


Fig. 15. Vertical distribution of water temperature, corresponding to Fig. 14.

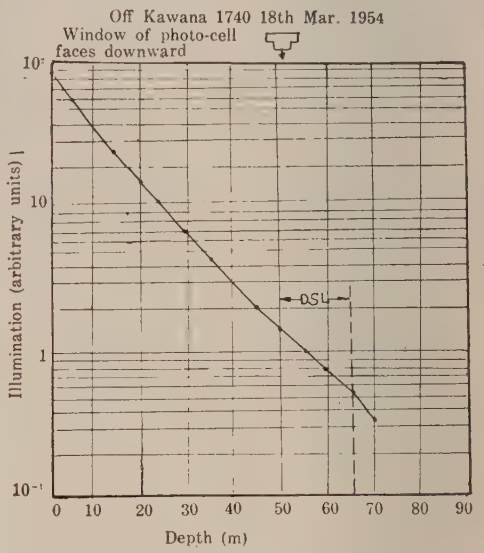


Fig. 16. Vertical distribution of submarine illumination.

4. Reflection Loss of Ultrasonic Wave on DSL

The reflection loss of the ultrasonic wave on DSL was measured by the indirect method and by the direct method, devised by the writers alike the

* The photometer and its measurement were made by members of the Sasaki Laboratory of the Scientific Research Institute.

method of measurement for the reflection loss on fish shoal explained in Technical Report of Fishing Boat Laboratory No. 6, March 1955.

(1) Reflection Loss of DSL by Indirect Method.

The result measured by the above mentioned indirect method by means of

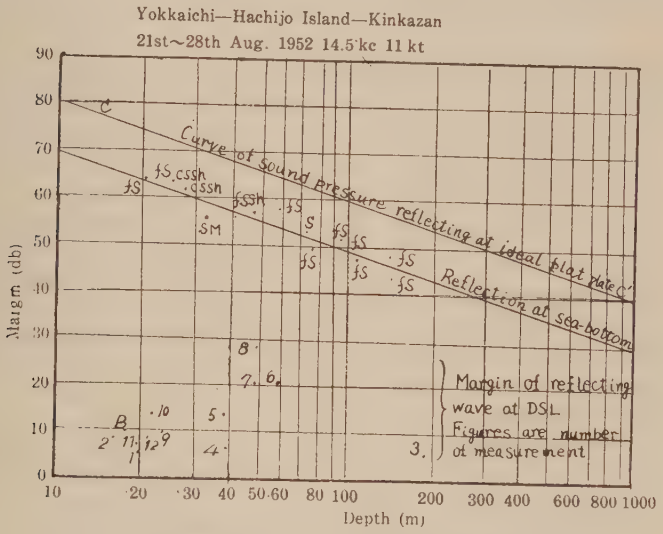

Yokkaichi—Hachijo Island—Kinkazan
21st~28th Aug. 1952 14.5 kc 11 kt
Margin (db)
Depth (m)
Curve of sound pressure reflecting at ideal flat plate c'
Reflection at sea-bottom
Margin of reflecting wave at DSL
Figures are number of measurement

Fig. 17. Reflection loss on DSL by indirect method.

the frequency of 14.5 kc on the course from Yokkaichi to Kinkazan via Hachijo Jima, is shown in Fig. 17. The sediments of the sea-bottom was fine sand in general, and the measured reflection loss on it was 8 db. Since the loss by run is 3 db assuming the bottom as a perfect reflecting plate and vertical to the progressing direction of the sound wave, the curve cc′ of the relation between the depth of the bottom and the margin of the reflected wave is parallel to the measured curve and lies above it by 11 db.

The writers have plotted the margin of the reflected wave from DSL at its depth, and obtained the reflection loss by the difference of that margin with the margin on the cc′ at the same depth. It ranges from

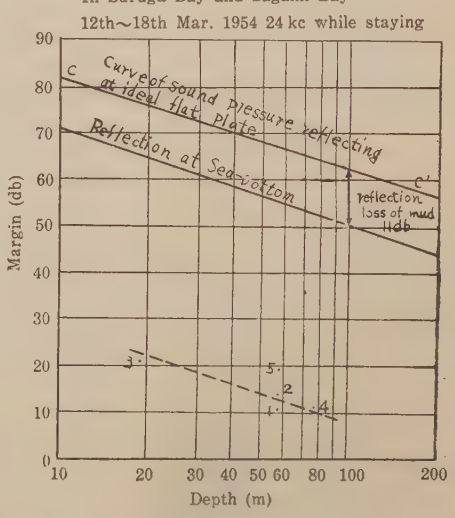

In Suruga Bay and Sagami Bay
12th~18th Mar. 1954 24 kc while staying
Margin (db)
Depth (m)
Curve of sound pressure reflecting at ideal flat plate
Reflection at Sea-bottom
Reflection loss of mud 11db

Fig. 18. Reflection loss on DSL by indirect method.

40 db to 70 db in Fig. 17.

The result of measurement by means of the frequency of 24 kc in Suruga Bay and Sagami Bay is shown in Fig. 18.

Since the ship was in staying condition and the sediment material of the sea-bottom was mud at that time, cc′ curve is plotted by adding 11 db like the previous case and consequently the reflection loss is 52 db to 56 db.

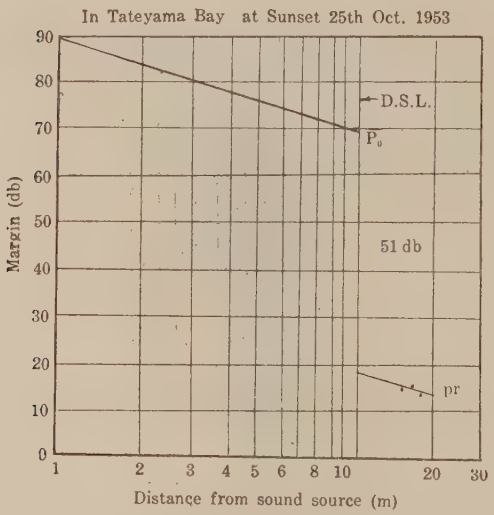


Fig. 19. Reflection loss on DSL by direct method.

(2) Reflection Loss on DSL by Direct Method.

The result measured by means of the frequency of 24 kc in Tateyama Bay is shown in Fig. 19.

Provided that the sound pressure of the incident wave to DSL is P_0 and that of the reflected wave on DSL is P_r, the reflection loss is as follows:

$$L = 20 \log_{10} \frac{P_0}{P_r}$$

In Fig. 19, the reflection loss on DSL by means of 24 kc is 51 db, and this is the measured value.

(3) Results of Measurement.

By the above mentioned measurement, the reflection loss of DSL is 40 db to 70 db by means of the range between 14.5 kc and 24 kc.

As the reflection loss on the shoal of anchovy measured in Tateyama Bay s 30 db, the reflection loss of DSL is 20 db more than it.

5. Conclusion

1. DSL appears at every station in the adjacent seas of Japan and is found especially at the shelf-edge zone and near the fishing banks, at the boundary of currents, in Summer and in Winter alike. It ascends after sunset and descends at sunrise and shows relation to submarine illumination and the station of its appearance seems to have some relation to fishing grounds.

2. It was illustrated that DSL at the fishing ground of Sergestes-shrimp off Yaizu was consisted mainly of Sergestes-shrimp mingled Salpa and zooplankton.

3. DSL is found at the thermocline frequently.

4. The reflection losses on DSL by means of the frequencies of 14.5 kc to 24 kc range from 40 db to 70 db. They are 52 db to 56 db at the fishing ground of Sergestes-shrimp.

5. Since DSL ascends to the sea-surface at night, its influence to horizontal propagation of the ultrasonic wave should be considered.

Reference

1) HASHIMOTO, T. 1953 Dec., Characteristics of Ultrasonic Waves Transmitted Vertically in Water, Report of Fishing Boat Laboratory, Fisheries Agency, Ministry of Agriculture and Forestry, No. 1.

Journal of the Tokyo University of Fisheries, Vol. 42, No. 2, 1956

STUDY OF DSL BY ULTRASONIC WAVE (2)

Tomiju Hashimoto and Yoshinobu Maniwa*

(Received Jan. 25, 1956)

1. Introduction

The writers examined the difference of the reflection losses and the records of DSL for the supersonic waves between the frequencies 24 kc and 200 kc. The writers measured the time of ascent and descent of DSL, and referred to its relation to illumination in water from the results of experiment.

2. Equipment of Experiment

The experiment was undertaken by the equipment shown in Table 1 on the board of Seichomaru of the Tokyo University of Fisheries.

Table 1

Type of Equipment	Frequency	Material of Transducer	Dimensions of Surface of Ultrasonic Transducer
F 50 A	200 kc	Titanic Acid Barium	40 mm ϕ
Type 1 of Fishing Boat Laboratory	24 kc	*AF* Alloy	80 mm × 130 mm

3. Results of Experiment

(1) Records of DSL

The experiments were made at the fishing grounds of Sergestes shrimp off Yaizu and Okitsu from 14th to 17th March in 1955.

When DSL was observed, attention was paid to keep the ship in staying condition at the almost same station.

DSL appeared at the shelf-edge of the bottom alike hitherto. The appearances of DSL pattern at the same station are shown in Fig. 4 to Fig. 7.

Fig. 4 and Fig. 5 show the records in the evening on 14th March. Fig. 6 and Fig. 7 show the appearances in the morning and the evening on 17th March. Time marks are put on the upper portion of the recording paper.

Fig. 1. Station of observation.

It was found that DSL ascends almost

* Fishing Boat Laboratory.

to the surface from the depth of 150 meters to 200 meters in dusk and descends to the depth of 200 meters to 300 meters in dawn and their velocities of vertical migration are about 3 meters/minute.

Table 2. Refiction Loss on DSL

Frequency *KC*	Reflection Loss *db*
24	76
200	70

(2) Difference of Reflection Loss on DSL due to Frequency.

The records obtained by 24 kc and 200 kc to be compared at the same time are shown in Fig. 5 and Fig 7. Since the transmitted energy of 24 kc is more than 200 kc, the records got by 24 kc are deep, but details in them are not known exactly. Minute records got by 200 kc can present the appearance of something such as small fishes mingled in the layer separately.

At 2105 in the evening on 17th March, the reflection loss on DSL at the depth of 20 meters was measured by 24 kc and 200 kc simultaneously as shown in Fig. 2 and Fig. 3. They are collected in Table 2 and it was found that the loss by 200 kc is less[1].

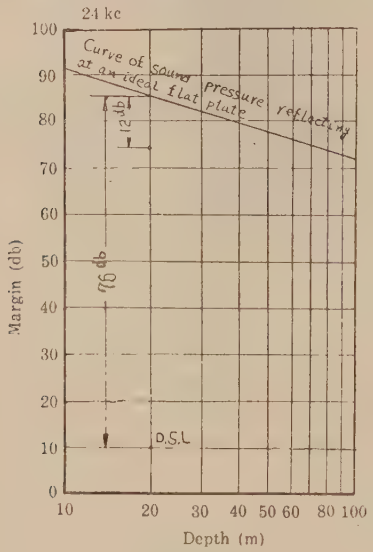


Fig. 2. Reflection loss on *DSL* by indirect method.

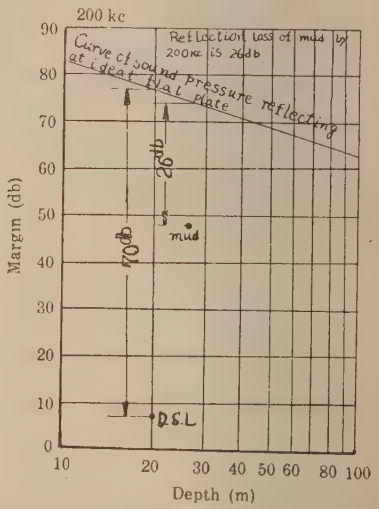
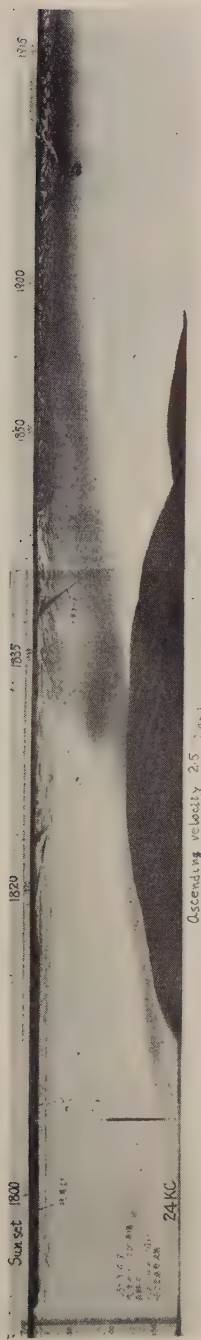


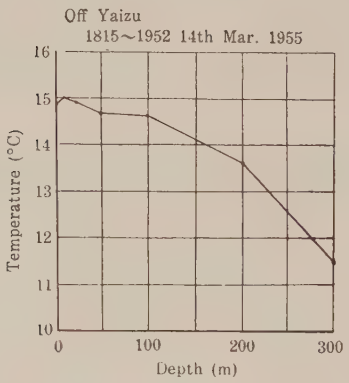
Fig. 3. Reflection loss on *DSL* by indirect method.

(3) Relation between Submarine Illumination and Vertical Migration of DSL.

The time variation curves of submarine illumination are shown in Fig. 4 and Fig. 6.

The variation of submarine illumination at the definite depth of 70 meters was observed from 0540 to 0637 in the morning on 17th and it corresponded to the variation of the depth of descending DSL. A slight gradient of the variation appeared from 17 minutes to 33 minutes after sunrise, and corresponding





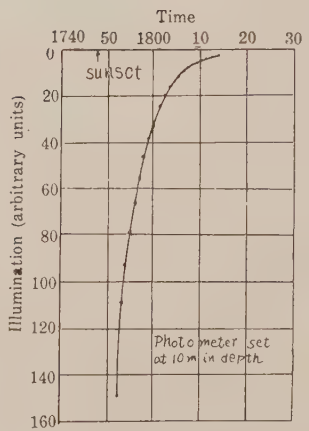


Fig. 4. Record by means of frequency of 24 kc at fishing ground of Sergestes-shrimp off Yaizu in evening on 14th March, and time variation curve of submarine illumination, and vertical distribution of water temperature.

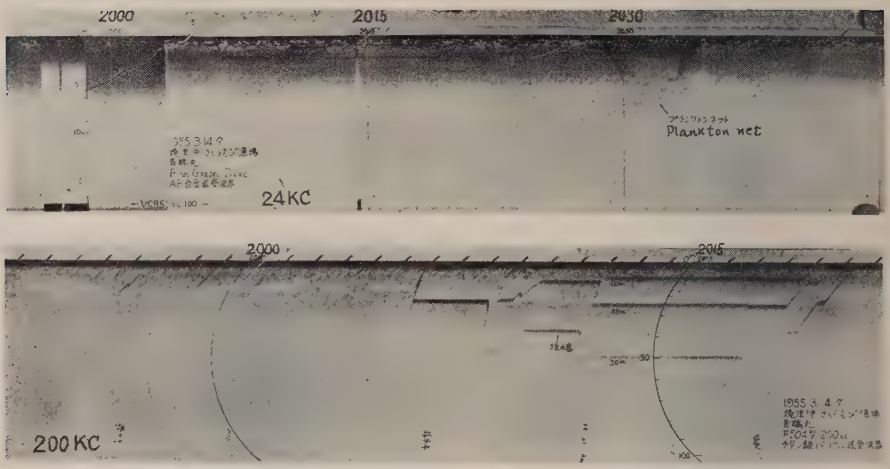


Fig. 5. Records compared by frequencies of 24 kc and 200 kc at fishing ground of Sergestes-shrimp off Yaizu in evening on 14th March.

to it, DSL ceased to descend. Then it was found that the variation of submarine illumination at the definite depth and the depth of the layer can be closely connected during this experiment.

(4) Variation of Water Temperature and Results of Collected Plankton.

The water temperature measured by reversing thermometers shows a conspicuous vertical gradient at 100 meters to 200 meters in every case. At 2028 to 2040 on 14th March, DSL lied near the surface and a plenty amount of plankton was caught there.

The results by a closing net (of GG-72 and 45cm in diameter) hauled from 2020 to 2040 on 17th March are shown in Table 3. A plenty amount of plankton are obtained at DSL.

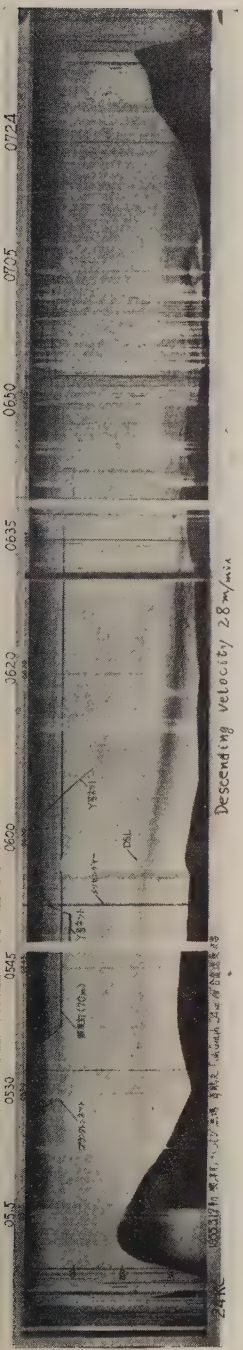
Table 3

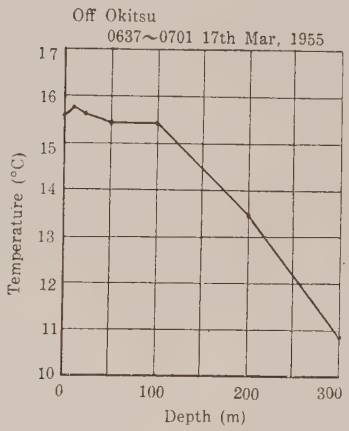
Depth of DSL	Depth of Haul	Number of Plankton Individuals Collected
0 m—30 m	50 m→ 0 m	14288
40 m—80 m	100 m→ 50 m	4640 (Euphausia is abundant)
No layer observed	150 m→100 m	1706

The temperature was measured by Uda Lab., the living organisms were collected by Matsue Lab. of the Tokyo University, Assistant Professor Yamaguchi and Captain Ozawa, and submarine illumination was measured by Sasaki Lab. of the Scientific Research Institute.

4. A Look of Our Experiments and Equipments

Fig. 8 and Fig. 9 show a look of our experiments and equipments.





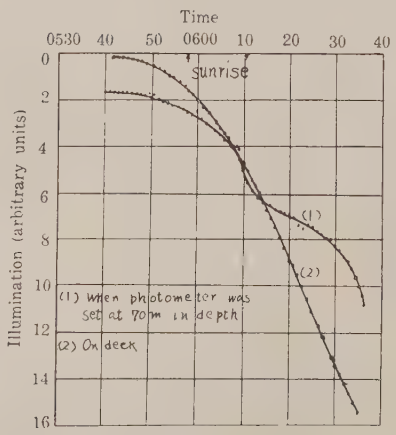
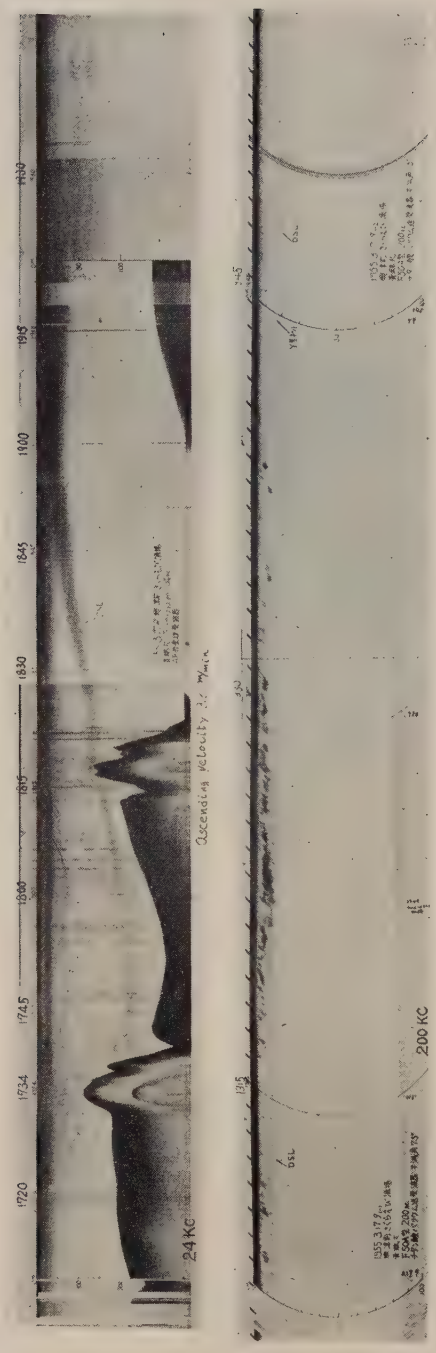


Fig. 6. Record by means of frequencies of 24 kc at fishing ground of Sergestes-shrimp off Okitsu in morning on 17th March, and time variation curve of submarine illumination, and vertical distribution of temperature.



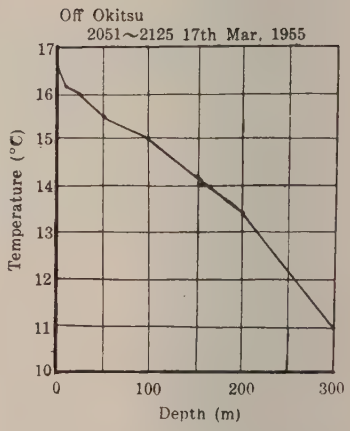


Fig. 7. Records compared by frequencies of 24 kc and 200 kc at fishing ground of Sergestes-shrimp off Okitsu in evening on 17th March, and vertical distribution of water temperature.

Fig. 8. Look of experiment.

Fig. 9. Fish finder.

5. Conclusion

(1) The vertical migration of DSL at 300 meters in depth was proved clearly at the same station.

(2) With regard to the frequency, the record got by 24 kc lies deeper than by 200 kc, due to its greater power, so the two can not be compared for that reason, but the reflection loss was less and the details were recorded better and shoals of fishes in DSL were found more clearly by means of 200 kc than by means of 24 kc.

(3) The appearance of descent of DSL corresponds to the variation of submarine illumination at the definite depth at the same time. The velocity of descent was 3 to 4 m/min.

Reference

1) HASHIMOTO, T. 1955 (Jan.). Characteristics of horizontal propagation of ultrasonic wave. Fishing Boat Laboratory, pp. 49.

Journal of the Tokyo University of Fisheries, Vol. 42, No. 2, 1956

RESULT OF EXPERIMENT ON REFLECTION OF ULTRASONIC WAVE DUE TO DIFFERENCES OF WATER TEMPERATURE AND DENSITY

Tomiju Hashimoto and Yoshinobu Maniwa*

(Received Jan. 25, 1956)

1. Introduction

It was already mentioned that the ultrasonic wave reflected at the boundary surface, when there was a layer at the boundary of fresh water in the upper layer and saline water in the lower layer, or when there is thermocline (discontinuity of temperature)[1].

In order to illustrate these phenomena, the writers made experiments on two mediums with different densities and water temperatures in contact artificially, and studied on the reflection loss on the boundary surface.

2. Equipment of Experiment

A vessel with the section of 0.5 m×0.5 m and the thickness of 10 cm made of a sheet of Polyethlene or gum is put in the wooden tank of the length of 24.5 m and the section of 0.5×0.5 m.

This vessel is named the measurement vessel. Fig. 1 shows the section of the tank, and the sender (*S*) is put at the centre at its one end, and the receiver (*R*) is put at 2 meters towards the sender from the vessel (*V*).

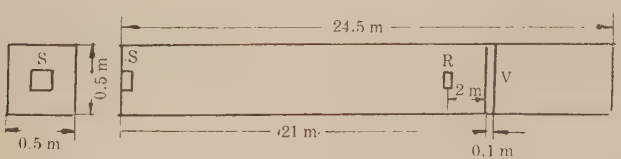


Fig. 1. Tank for experiment.

This measurement vessel (*V*) is framed by an iron plate of the thickness of 1 mm and the breadth of 10 cm. The both surfaces are put on by a sheet of Polyethylene of the thickness of 0.05 mm or gum of the thickness of 0.3 mm.

The senders and the receivers used are magneto-striction vibrators, and the areas of the sender and the receiver of 28 kc are 11.2 cm×11.2 cm and 6.4 cm×1.9 cm respectively and those of 42.8 kc are 15 cm×15 cm and 6.4 cm×1.4 cm respectively.

* Fishing Boat Laboratory.

3. Method of Experiment

Pure water is filled in the tank, and water with different density or temperature is poured into the vessel, and when the ultrasonic wave is transmitted from the sender put at the end of the tank to the other end, it propagates to the receiver in the tank, as shown in Fig. 1. This wave is named the direct wave. The wave propagates to the test water with different density or temperature and its most part permeating the test water propagates to the other end of the tank but other part reflected at the test water returns to the receiver. The latter is named the reflected wave. Then the reflection loss is expressed as

$$L=20\log_{10}\frac{P_0}{P_r} \quad \cdots\cdots (1)$$

provided that P_0 is the sound pressure of the incident wave to the medium with different density and temperature and P_r is the sound pressure of the reflected wave from that medium.

If we put the margins of P_0 and P_r, M_0 and M_r respectively, the reflection loss L is

$$L=M_0-M_r\,(\mathrm{db}) \quad \cdots\cdots (2)$$

In this measurement, the acoustic characteristics of the measurement vessel and the tank are important. With respect to the tank, as it is expressed by experimental values in Chapter 3 of the reference 1) and the reference 2) the distributions of sound pressures of the direct waves of both 28 kc and 42.8 kc are almost uniform at the range from 18 meters to 21 meters off the sender.

Accordingly, the reflection loss is got by the expression (2) by measured margins of P_0 and P_r at the point shown in Fig. 1.

4. Characteristics of Propagation of Ultrasonic Wave at Measurement Vessels

Pure water in the tank is filled in the measurment vessel, and margins of P_0 and P_r, M_0 and M_r, are measured by means of 28 kc and the results are shown in Fig. 2 and Fig. 3. The reflection loss L_r of the measurement vessel is 54 db for a gum sheet and 58 db for a Polyethylene sheet. Using 42.8 kc, it is 57 db for a Polyethylene sheet as shown in Fig. 4.

A gum sheet taken away, the reflection loss of the frame alone is measured by 42.8 kc in the same condition, and consequently it is more than 80 db. Therefore the reflection from the frame alone is not very important.

5. Reflection Loss L of Ultrasonic Wave due to Difference of Densities

Using the measurement vessel of a gum sheet mentioned in 4., measurement was made at 30 minutes after pouring saline water cooled sufficiently after boiled into it.

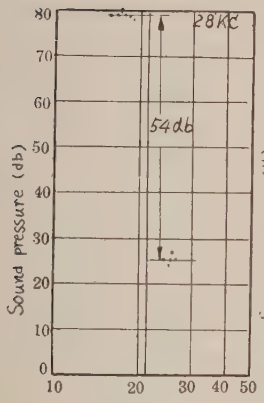


Fig. 2. Reflection loss of measurement vessel made of gum sheet.

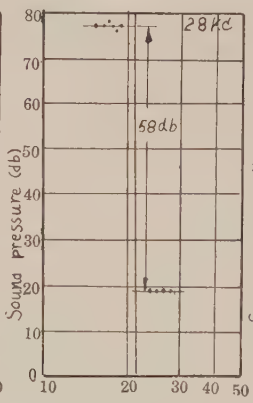


Fig. 3. Reflection loss of measurement vessel made of Polyethylene sheet.

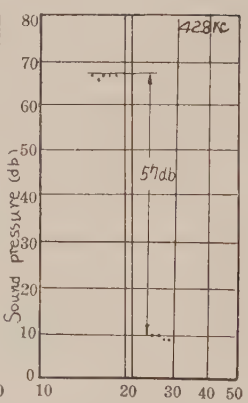


Fig. 4. Reflection loss of measurement vessel made of Polyethylene sheet.

Fig. 5. Measurement vessel made of gum sheet.

Fig. 6. Measurement vessel made of Polyethylene sheet.

Provided that densities and propagating velocities of sound wave in the mediums in the tank and the measurement vessel are ρ_1, ρ_2 and C_1, C_2 respectively, the reflection loss L_ρ of ultrasonic wave due to the difference of densities is as follows[3]:

$$L = 20 \log_{10} \sqrt{\left(\frac{\rho_1 C_1}{\rho_2 C_2} - \frac{\rho_2 C_2}{\rho_1 C_1}\right)^2 \Big/ 4 \cot^2 \frac{2\pi l}{\lambda} + \left(\frac{\rho_1 C_1}{\rho_2 C_2} + \frac{\rho_2 C_2}{\rho_1 C_1}\right)^2} \quad \cdots\cdots (3)$$

l: thickness of the measurement vessel
λ: wave length of sound wave, propagating in the medium in the measurement vessel.

Then the measured values and the calculated values by the expression (3) are shown in Fig. 7 and both agree.

When the difference of densities 0.019 is expressed by salinity σ, it is 24‰ by the experimental formula (4)[4] introduced by M. KNUDSEN. In this case, the reflection loss L_ρ at this boundary surface is 37 db as shown in Fig. 7.

$$\rho_2 = 1 + 0.0008\sigma \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \quad (4)$$

Let us consider the case that the ultrasonic wave enters normally into a boundary layer in the sea, made by pure water and sea-water. The velocities (C_1, C_2) of sound waves in water with various densities and temperatures are got by "Table of Velocity of Sound in Pure Water and Sea-water for Use in Echo Sounding and Sound Ranging, London 1927, Hydrographic Department of British Admiralty." The reflection coefficient in sound pressure φ_ρ is

$$\varphi_\rho = \left| \frac{\rho_1 C_1 - \rho_2 C_2}{\rho_1 C_1 + \rho_2 C_2} \right| \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \quad (5)$$

The reflection loss L_ρ is shown as (6) using (5)

$$L_\rho = 20 \log_{10} \frac{1}{\varphi_\rho} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \quad (6)$$

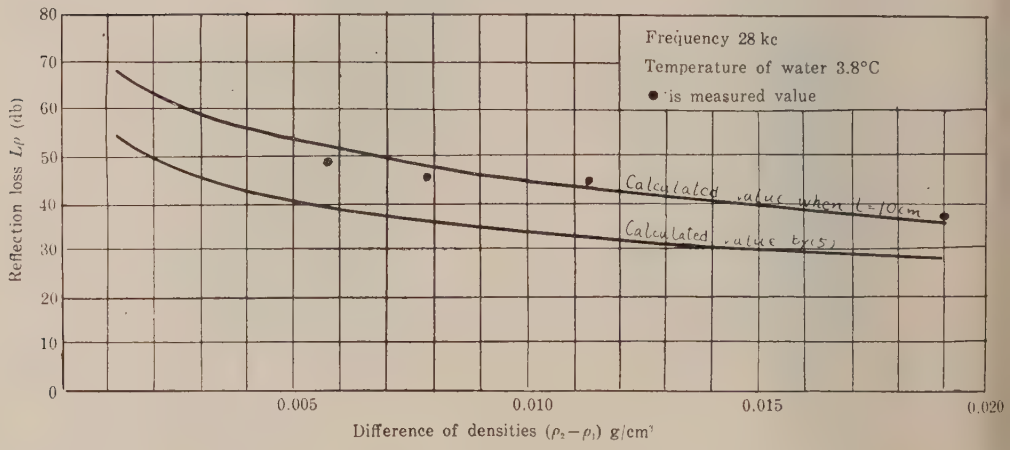


Fig. 7. Reflection loss due to difference of densities.

6. Reflection Loss L_t of Ultrasonic Wave due to Difference of Temperatures

Even if the medium of different temperature from the medium in the tank is poured in the measurement vessel, heat is transferred from higher temperature to lower one, and bubbles grow at the boundary, but it is difficult to separate these phenomena, therefore the reflection loss L_t of ultrasonic wave due to the difference of temperatures is considered as involving these phenomena.

The writers poured hot water (about 40°C) into the measurement vessel

step by step and mingled it deliberately and made measurement at 5 minutes after bubbles vanished. The distribution of temperature was measured by a mercurial thermometer at A, B and C in Fig. 8 while measuring.

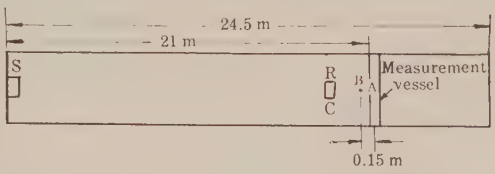


Fig. 8. A Look of experiment.

The reflection loss L_t of the ultrasonic wave due to the difference of temperatures is obtained like L_ρ mentioned in 5.

Then L_t is shown by the formula

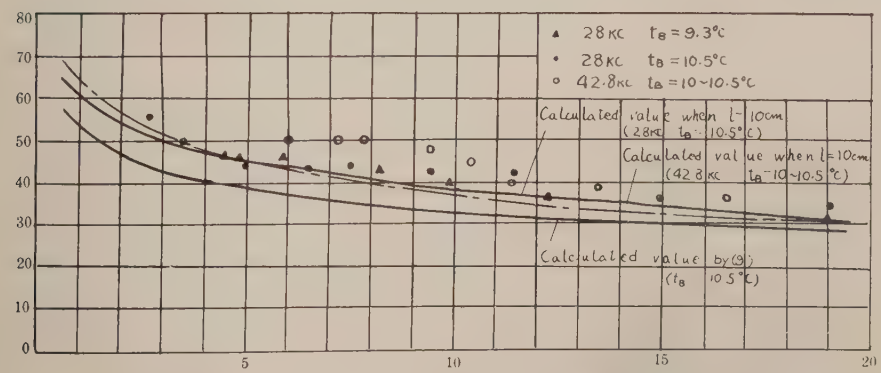
$$L_t = 20 \log_{10} \frac{P_0}{P_r} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \quad (7)$$

The measured reflection loss L_t and its calculated values by the formula (3) in 5 are shown in Fig. 9 for comparison.

We are afraid that heat is transferred and bubbles grow at the boundary of temperature as mentioned above but as the calculated values agree with the measured values very nearly, the values calculated by (3) is precise.

When the same mediums with different temperatures border, making a boundary surface and the ultrasonic wave enters normally into it, if variation of density by the difference of temperatures is neglected for its scanty value, from (5) the reflection coefficient of sound pressure φ_t is considered as

$$\varphi_t = \frac{\Delta C}{C_1 + C_2} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \quad (8)$$



Difference of temperatures $(t_A - t_B)$°C provided that t_A and t_B are temperatures at A and B.

Fig. 9. Reflection loss due to difference of temperatures.

Provided that $\Delta C = C_2 - C_1$

$$L_t = 20 \log_{10} \frac{1}{\varphi_t} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \quad (9)$$

φ_t is about $\frac{1}{1000}$, as ΔC is about 4 m/s at about 10°C when the difference of temperatures is 1°C.

7. Results of Experiments

Following matters are concluded from above results of the experiments.

1. It can be explained that, at a river-mouth where sea-water and river-water with different densities meet, a layer appears on the echogram by sound wave reflected at the boundary surface.

2. It may be explained that the sound wave is reflected at the depth with remarkable variation of temperature, that is to say, a thermocline layer in a sea or a lake, and it is reflected at a clear boundary layer of the Kuroshio Current and the Oyashio Current, and the boundary layer is recorded on the echogram.

For example, the record of the reflection on the boundary layer of the sea water and the river water at the estuary of Shinano River is shown in Fig. 10.

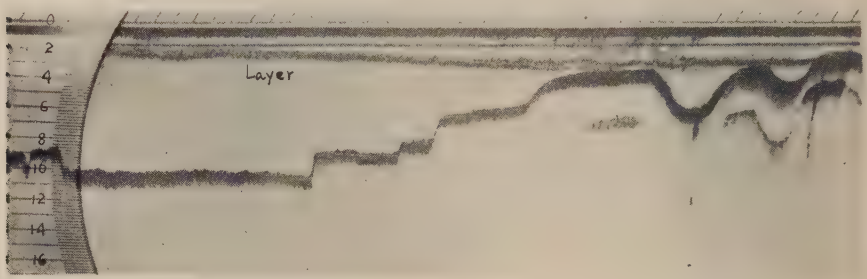


Fig. 10. Record of reflection on boundary of mixed water at Shinano river-estuary. (Offered by Oki Electric Industry Co.)

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OBSERVATIONS ON THE SO-CALLED DEEP SCATTERING LAYER (D.S.L.), WITH SPECIAL REFERENCE TO THE VERTICAL DISTRIBUTION OF PLANKTON

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(Received Jan. 25, 1956)

Introduction

Since Eyring, Christensen and Raitt detected the curious layer which scatters ultra-sonic sounds in the offshore waters of California, numerous observations have confirmed that so-called "Deep Scattering Layer (D.S.L.)" exists over considerable wide areas of the oceans at the depth of several hundred meters at daytime, and that it ascends to the sea surface at night and descends again to the depths at day-break. It would be impossible to seek such a character in physical discontinuities. On the other hand, as it has been known that many sorts of marine free-living organisms migrate vertically with the variation of light intensity, most authorities agree that this scattering layer must be formed by crowds of marine organisms, such as fishes, squids or macro-plankton (Johnson, Hersey, Davis,

Table I. Summary of the investigations of the ultra-sonic scattering layer.

No. of investigation	Period	The area investigated	Research Vessel	Frequency of echo-sounder
1	Aug., 21–28, 1952	Along the coast of Honsyu, from Daiozaki to Kinkazan	Umitaka-maru	24 kc.
2	Sep., 10–13, 1952	Suruga Bay	Seicho-maru	24 14.5
3	Dec., 4–13, 1952	Beppu Bay, along the coast of Shikoku and Honsyu through Bungo channel	Umitaka-maru	24 14.5
4	Feb., 12–20, 1953	Surrounding area of Izu Peninsula	Umitaka-maru	24
5	Oct., 24–26, 1953	Tateyama Bay	Seicho-maru	24 50
6	Mar., 12–18, 1954	Suruga and Sagami Bay	Seicho-maru	24
7	Oct., 16–19, 1954	Tateyama Bay	Seicho-maru	200 24
8	Mar., 14–19 1955	Suruga Bay	Seicho-maru	200 24

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LYMAN, MOORE, DIETZ, BODEN, TUCKER and MARSHALL etc.). Although this opinion is convenient to explain the phenomenon, the results of any observation have not been conclusive.

We have studied this phenomenon in collaboration with Dr. UDA and many other colleagues in the adjacent sea of Japan (Table I). We alloted to observe the scattering layer referring to the vertical distribution of plankton throughout the investigations.

Methods and apparatus

The plankton collections by a closing net were carried out, while the survey by the echo-sounder was made. The net hauled vertically in the layer where the scattering layer was detected, and also in both layers above and below this. In some cases we were obliged to abandon the hauling in the depths below the scattering layer, because the scattering layer was found very close to the sea bottom. And in the first investigation the net was hauled to the sea surface at each hauling, as the closing apparatus of the net was damaged at the first hauling. The length of wire to be paid out for a given depth was calculated by cosine of a wire angle.

In present paper we will confine ourselves in discussing the results of the first, second, third, sixth and eighth investigations, because in other three investigations the available data were not obtained to discuss the correlation between the scattering layer and the vertical distribution of plankton.

In the first three investigations the closing net with 71 cm mouth diameter and GG-72 bolting cloth (27.3 meshes/cm) was used for plankton collections, and in the last two investigations the closing net with 45 cm mouth diameter and GG-72 bolting cloth was used.

The first investigation

In the first investigation we recorded the scattering layer at stations shown in Table II.

At station 1, about 20 miles south-eastwards away from Daiozaki, the scattering layer was found in the depth of about 400 m. Among animals collected by a single haul from the depth of 400 m to the surface, larger Copepoda, such as *Calanus*, *Eucalanus*, *Euchaeta* and *Pleuromamma* etc., Chaetognatha, Euphausiacea, *Lucifer raynaudii* were dominant, and also a shrimp belonging to Sergestidae was obtained. It may be imprudent to infer that these animals accumulated at the depths where the scatttering layer was detected, because the collection was restricted to a single haul, and because it is probable that these animals ascended to the sea surface at night, when the collection was made.

At station S-1, on Shinkurose Bank, it could be hardly found any quantitative and qualitative differences between the sample collected while the echo-sounder was detecting the scattering layer and that collected at another time on this Bank. This applied to station 14′ too.

Samples collected at station 22 and 27, both of which were occupied in the area under the influence of Oyashiwo Current, showed a qualitative difference

compared with those collected at stations above mentioned. Namely cold water forms, such as *Calanus plumchrus*, *Scolecithricella minor* and *Sagitta elegans* etc. occurred dominantly. But from the results of these collections the direct correlation between the scattering layer and the distribution of plankton was not obtained. The plankton communities at stations where the scattering layers were detected were shown in Table III, throughout four investigations described in this report, excepting the third investigation.

Table II. Stations where the scattering layer was detected, in the first investigation.

St. No.	Latitude Longitude	Time	Depth of D.S.L. (m)	Remarks
1.	34–08.4°N 137–14.9°E	18–30	400	The station in the marginal region of Kuroshiwo Curr., Depth; ca. 2,000 m.
S–1.	33–33.4°N 140–04.6°E	19–30 20–10	50–70 75–85	On Shinkurose Bank, Depth; ca. 180 m.
14′.	37–14.6°N 141–36.5°E	19–30	45–60	On the continental slope off Shioya-zaki, Depth; 250–300 m.
22.	38–36.1°N 144–17.1°E	04–00 05–00	200	The marks of fish crowds was recorded simultaneously with D.S.L.
27.	38–08.9°N 141–38.0°E	03–00	120–160	Off Kinkazan, Depth; ca. 160 m.

The second investigation

For discussing the correlation between the scattering layer and the distribution of plankton, our attention must be paid especially at the vertical distribution of larger forms. For the sake of convenience plankton animals were divided into two groups, larger and smaller than a limit of 2 mm in body length. The number of individuals of the larger group, the total number of zooplankton and the displacement volume in each layer were shown in Fig. 1 respectively. This applies to such cases as the sixth and eighth investigation described below.

As a whole in the depth where the scattering layer was detected any quantitative and qualitative difference could be found compared with in the other layers. At station 5 the quantity of plankton in such layer was rather small compared with those in both layers of deeper and shallower depths. At station 2 and 3, considerable quantity of Medusae was collected, but it is supposed that their distribution is restricted in shallow layer near the surface and they have hardly relation with the scattering layer. The representatives of larger forms were *Calanus helgolandicus*, *Eucalanus subcrassus*, Furcillia stages of Euphausiacea and Chaetognatha etc. in this area, but it was supposed that they had no relation with the scattering layer.

It was day-break when the observation was made at station 3, then the descent of the scattering layer was observed, its descending speed was 0.9–2.0

m/min., 1.25 m/min. in average. This value is within the range of value reported as migration speed of the scattering layer in recent papers.

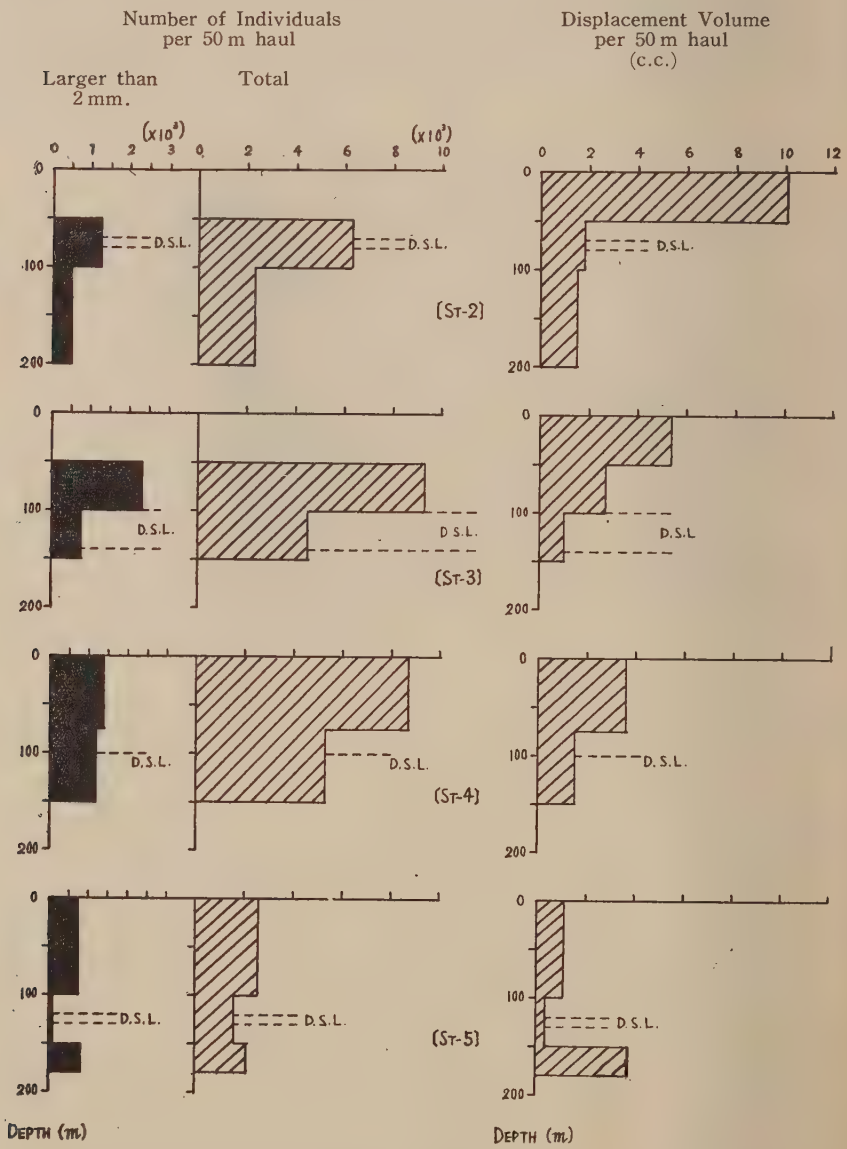

Fig. 1. The vertical distributions of plankton in the second investigation.

The third investigation

In this case we navigated from Shimonoseki to Ito through Bungo Channel and along the coast of Shikoku and Honshyu, but the scattering layer was found only in Beppu Bay.

At Beppu Bay the scattering layer could not be observed in daytime at all, and occurred toward the sunset near the sea bottom then began to ascend gradually, and reached the sea surface soon. It began to descend again just

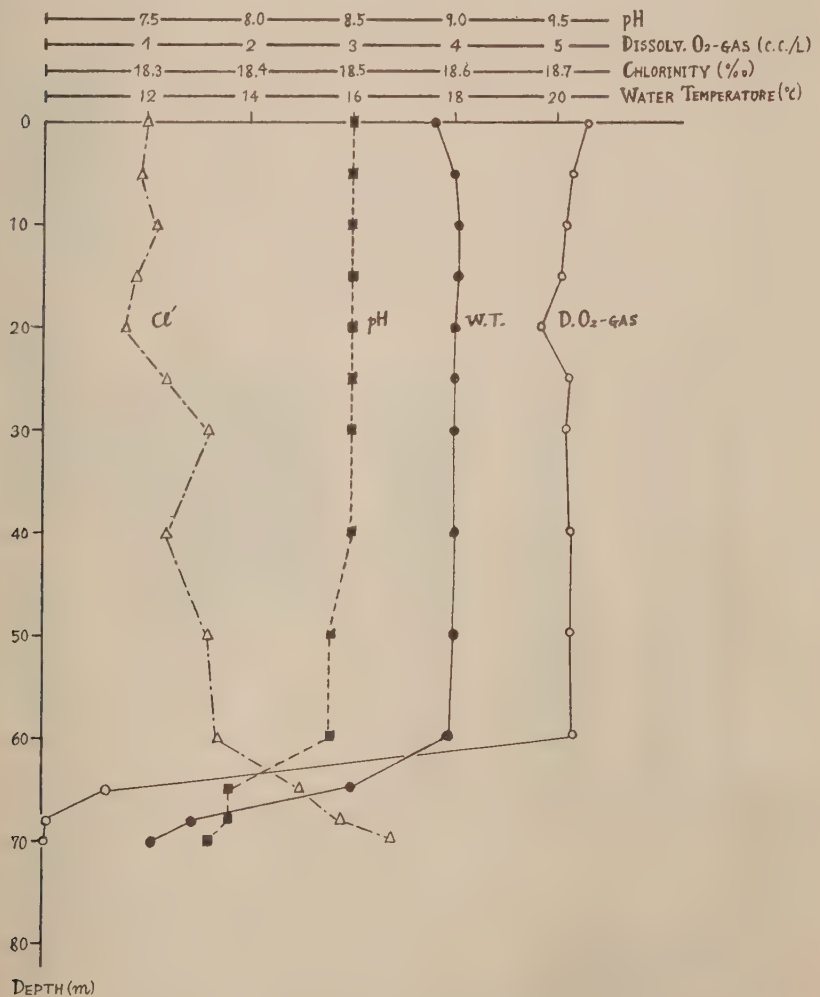

Fig. 2. The vertical distributions of water temperature, chlorinity, dissolved oxygen and hydrogen-ion concentration at the deepest point in Beppu Bay, in the third investigation.

before the twilight and disappeared soon after the sunrise. The ascending speed was 0.5–1.1 m/min., but the descending speed could hardly determind, as the process of the descending and disappearance was very obscure.

When the observation was carried out, water temperature showed us a uniform value of 18.0°C from the surface to the bottom. The average depth of this bay is about 60 m. On the other hand, in the deepest point that is in the interior part of the bay and have about 75 m in depth, there was stagnant water in the layer lying deeper than 60 m, as shown in Fig. 2. And in this layer dissolved oxygen was very scarce. While the observation at this point confirmed that the scattering layer never occurred in such oxygen lacking layer. It must be a strong proof that the scattering layer is biological origin.

However, the quantity of zooplankton in this area was very poor. In each haul from the bottom to the surface, we were able to collect nothing but scores of *Calanus helgolandicus*, a few Polychaeta larvae, several hundreds of small Copedoda, such as *Paracalanus parvis*, *Acrocalanus gibber*, *Corycaeus japonicus*, *Oithona similis* etc. On the other hand, phytoplankton, Diatom, propagated abundantly.

The fluctuation of the vertical distribution of plankton was shown in Fig. 3, from the sunset to the sunrise. But this fluctuation was not coinsident to the vertical migration of the scattering layer.

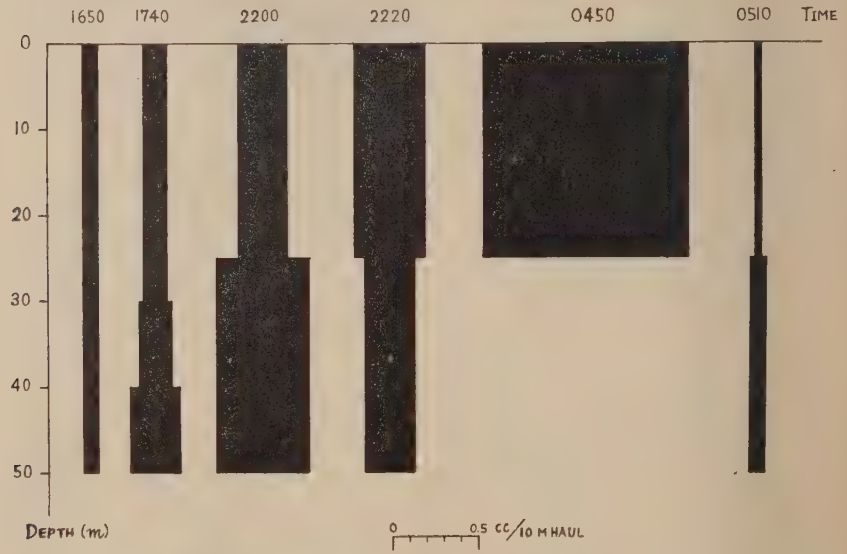

Fig. 3. The fluctuation of the vertical distribution of plankton through the night of December 4th, 1952 at Beppu Bay, in the third investigation.

The sixth and eighth investigation

These investigation were carried out at Suruga Bay in March. It was supposed that the main scatterers of ultrasonic sounds in this Bay may be crowds

of Sakura-ebi, small shrimp so-called in Japanese—*Sergestes lucens*, prior to investigation. Suruga Bay has excellent fishing grounds of this shrimp along the coast, and it was the fishing season when the investigations were carried out. It

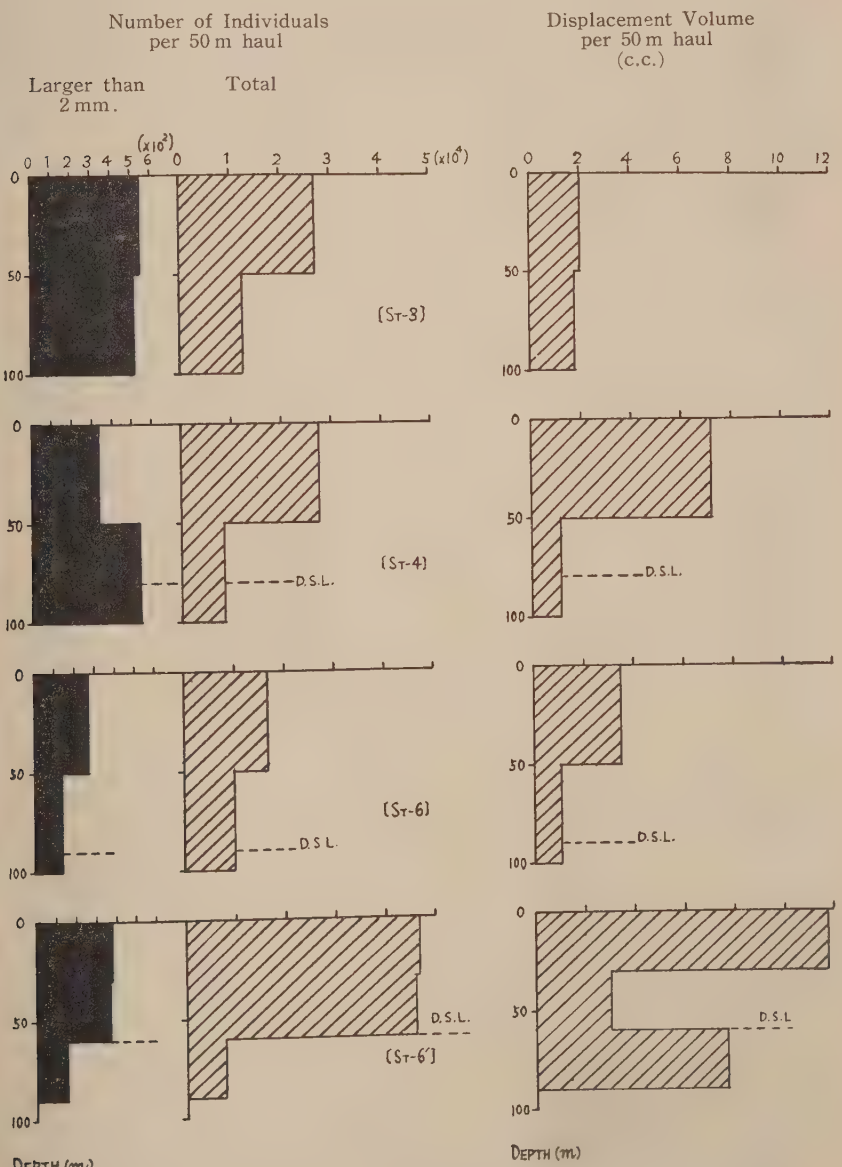

Fig. 4. The vertical distributions of plankton in the sixth investigation.

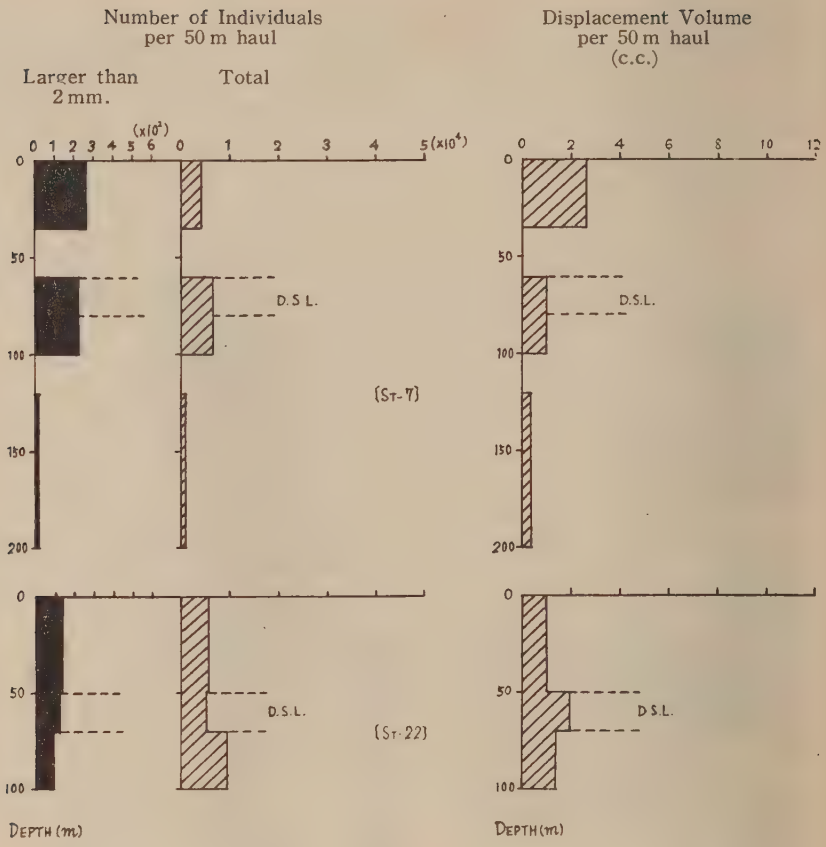

Fig. 4 (continued). The vertical distributions of plankton in the sixth investigation.

will be valuable to study the relation between the scattering layer and the behaviour of this shrimp for the solution of the question in adjacent sea of Japan.

As the larger and special nets were prepared for the collection of this shrimp by Prof. IHARA and Assis. Prof. YAMAGUCHI, we followed the former methods and used a similar type of net.

The results of observations on the vertical distributions of plankton in the sixth investigation were shown in Fig. 4. As a whole, it could be observed that a great number of small Copepoda, such as *Paracalanus parvus*, accumulated in the surface layer. It can be pointed out that the quantity of plankton in the upper layer was larger than that in the depths where the scattering layer was found. But at station 6′ and 7, where three hauls covering three layers could be made, the quantity of plankton in the lower layer was smaller than that in the depths where the scattering layer was found. About larger Copepoda with body length larger than 2 mm and Euphausiacea, it seemed that they tended to concentrate in the depths where the scattering layer was found. But this tendency

was not always the case throughout all stations. At station 4 a good number of *Salpa fusiformis*, with body length about 20 mm, was captured by hauls in a restricted layer near the surface up to 30 m. The scattering layer was detected not only at the depth of about 80 m, but also near the surface at the depth of about 20 m at this station. It was difficult to discriminate between the scattering layer and the dispatching signal of the echo-sounder in such a case. At station 22 the scattering layer ascended at the average speed of 2.5 m/min.

The vertical distributions of plankton in eighth investigation were shown in Fig. 5. In this case the result of observations was similar to that of former

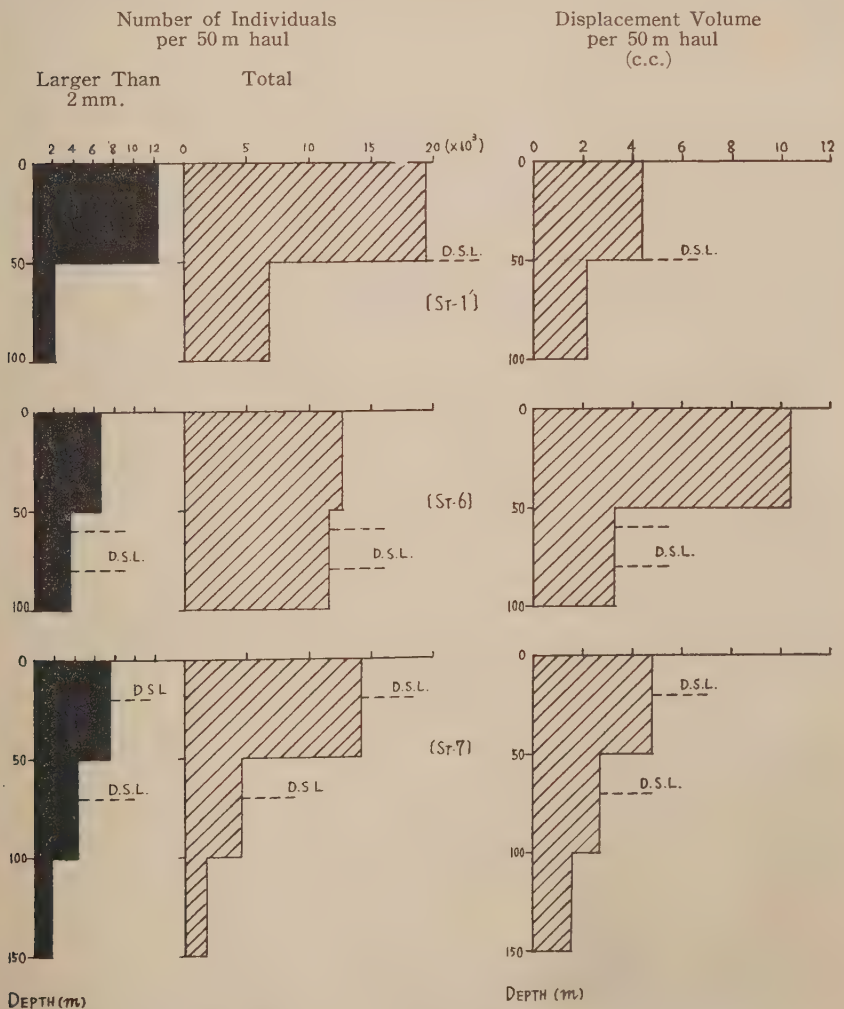

Fig. 5. The vertical distributions of plankton in eighth investigation.

cases. It could be hardly observed that any sort of plankton concentrated in the depths where the scattering layer was detected. On the evening of the 14th the scattering layer ascended from the depth of about 150 m toward the surface at the average speed of 2.2 m/min., on the evening of the 17th it ascended from the depth of about 220 m at the speed of 2.8 m/min. In the morning of the 15th the layer descended from the depth of about 100 m to 150 m at the speed of 2.5 m/min., and in the morning of 17th it descended from the depth of about 210 m to 300 m at the speed of 2.6 m/min. These values of migration speed of the scattering layer within the range of values that ever reported as the speed of vertical migration of zooplankton by many authors.

Discussion and conclusion

The scattering layer was detected not only in the open sea but also in the coastal waters such as Beppu Bay and Suruga Bay throughout our investigations.

From the results of observations, it was hardly impossible to seek for the correlation between the scattering layer and the vertical distribution of plankton, so far we studied. But our attention must be paid at points that the nets used in these investigations might be not favourable for collections of organisms acted as scatterer of ultra-sonic sounds, and that the speed of net hauling, which was limited by the power of the equipment of the vessels, was not suitable for this purpose.

On the other hand, the fact that at Beppu Bay the scattering layer was never detected in the dissolved oxygen lacking layer is a strong proof that the scatterer must be a animal crowd. The scattering layer were found in regions such as on bank, along continental slope, at the marginal region of a current or current rip. It has been known that in these regions, plankton or the other marine organisms are propagated or accumulated abundantly.

And the scattering layer has a tendency to be detected about the sunset or the sunrise apparently. It seems that this tendency has a connection with the behaviour of plankton or the other free-living marine organisms to make a dense crowd at these times of a day. It is very difficult to draw a clear line between the scattering layer and the despatching signal of the echo-sounder when the scattering layer ascends to the sea surface. It may be caused by a dense crowd of plankton, even if they are small in size, that the despatching signal of the echo-sounder is recorded as a long mark on the recording paper, referring the case of Suruga Bay.

It must be strongly desired the more extensive ecological survey of animals which may play the rôle of the scatterer of ultra-sonic sounds, with the simultaneous examination by the echo-sounder.

Summary

Observations on the scattering layer of ultra-sonic sounds were made, with the special reference to the vertical distributions of plankton, throughout eight investigations in the adjacent sea of Japan. The direct correlation between the

scattering layer and the vertical distribution of plankton was not obtained apparently, but it was found some interesting facts on the feature of the scattering layer in connection with the behaviour of plankton ever reported.

Acknowledgments

We are indepted to Dr. UDA and many other colleagues in this study for their hearty collaboration throughout investigations. And our thanks due to Messrs. SANO, NAGAYA and ENDO, students of University of Tokyo, for their efforts in our plankton collections.

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	No. of Invest.	The first investigation							
	Station	1	S_1		14′		22		
	Location (°N / °E)	34–08.4 / 137–14.9	33–33.4 / 140–04.6		37–14.6 / 141–36.5		38–36.1 / 144–17.1		
	Date	8–21	8–23		8–25		8–27		
	Time	19–30	20–45	20–30	20–00	19–45	04–55	05–13	(
	Hauled layer (m)	400– 0	50– 0	100– 0	50– 0	100– 0	100– 0	300– 0	1(
	Wire angle	36	—	—	40	30	52	34	
	Displac. Vol. (cc)	5.8	4.6	4.7	4.8	3.7	6.3	9.7	
Protozoa	Noctiluca								
	Radiolaria								
	Foraminifera								
	Tintinnoinea								
	Dimoflagellata								
	Medusae	2	708	708	34,108	2,278	8,854	3,005	1
	Chaetognatha	350	278	222	680	752	1,934	678	
	Annelida	50	224	212	6	242	241	531	
Crustacea	Copepoda	6,620	22,856	10,282	12,176	18,224	18,943	14,862	25
	Copepoda Nauplii	50		100			1,864	668	1
	Cladocera	900		100	2,900	1,332	2,097	501	
	Ostracoda	150	600	400			233	374	
	Cirripedia Nauplii								
	Euphausiacea	135		6	66	80		30	
	Amphipoda	50	6	106	6	30	8	11	
	Lucifer raynaudii	100	60	6			8	30	
	Mysis L.		42	402	130	60	48	277	
	Zoea & Megalopa L.		6	306	500	444	699	10	
	Others	3							
Mollusca	Gastropoda L.		106	212	18	666	2,097		
	Pelecypopa L.						233		
	Cephalopoda L.	2				20			
	Appendicularia	300	4,496	1,296	2,536	3,340	2,129	334	4
	Thaliacea		24	278	1,880	686	1,181	187	
	Fish egg				100	222	466		1
	Larval fish	1	6	18		40			
	TOTAL	8,713	29,412	15,652	55,206	28,416	41,035	21,498	35

Table III. The plankton communities at stations where the scattering layers w

		The second investigation										
27		1	2		3		4		5			
(38-08.9 (141-38.0		(35-04.4 (138-44.7	(35-05.8 (138-40.0		(34-57.6 (138-22.2		(35-03.4 (138-47.2		(35-04.3 (138-48.0			(
8-28		9-10	9-10		9-11		9-11		9-13			
04-10	04-00	15-40	18-30		06-00		13-00			06-00		05-
00- 0	230- 0	100-50	200-100	100-50	150-100	100-50	150-75	75-0	180-050	150-100	100-0	100-
—	30	30	45	40	45	—	35	50	25	50	20	
6.1	5.2	2.3	3.0	1.8	1.0	2.7	2.2	5.4	2.3	0.4	2.3	
,200	424	101	30	88	53	89		293		2	73	
383	906	223	36	167	274	566	197	427		40	64	
27	6	51	10	21	20	56	100	23		11	40	
,128	35,606	7,192	4,196	5,291	1,949	5,701	6,835	8,095	1,194	1,336	4,010	12,3
,800	2,806											
300	400	120		100	1,660	1,836	140	3,374		22	620	
27	30	200	90	180	160	108	220	100		77	160	
		20	10	40	60	108	40	60		11	20	
45	84	198	113	145	42	140	129	224		34	54	
36	18	22		1	20	27	2	43			20	
		2		7	2	13	2	73			29	
270	174	24	10	40	42	163	3	62			42	
9	800	3		1		30		40		1		
		1	5			1		20				
	206	20				27	20			44	40	
						27	20	20				
,779	2,630	482	90	202	241	385	200	220		22	60	
	6	21	7	1				40				
,209			110							11		
				1	20	1				11		
,213	44,096	8,678	4,587	6,285	4,441	9,278	7,905	13,114	1,260	1,622	5,293	12,5

detected, in the first, second, sixth and eighth investigations.

	The sixth investigation													The eighth investigation						
	4		6		6′			7		22				1′	6		7			
.4 .9	(34–51.1 (138–21.2		(— (—		(34–51.2 (138–22.2			(34–50.9 (138–21.4						(34–51.8 (138–33.6	(35–02.9 (138–33.6		(35–02.6 (138–34.0			
	3–18		3–14		3–14			3–14		3–18				3–14	3–17		3–17			
05–45	18–00	18–05	16–25	16–35	17–25	17–37	17–44	19–27	19–19	19–39	17–26	17–33	17–40	20–28	20–40	05–28	05–35	20–20	20–32	20–39
50– 0	100–50	50– 0	100–50	50– 0	90–60	60–30	30– 0	200–120	100–60	35– 0	100–50	50– 0	70–50	100–50	50– 0	100–50	50– 0	150–100	100–50	50– 0
35	38	36	36	39	40	40	30	30	33	24	—	—	—	5	13	16	2	0	0	0
2.0	1.2	7.2	1.1	3.5	4.6	1.8	7.1	0.6	0.8	1.8	1.4	1.0	0.8	2.2	4.6	3.3	10.4	1.6	2.7	4.8
60	40	100	70	40	40		20							40	40		80		20	360
				10										20	20					
			70	160				20	40	20	80	30	10			40				40
		130	40	20																
			30											40	680	80	220		120	200
220	88	474	50	25	64	150	85		2	4	151	243	121				40			300
50	79	68	24	27	48		56		18	67	14	4	2	24	25	6	60	1	20	43
		15		2	1	2		1	1	1		10			40		40			60
5,665	7,683	25,750	9,185	15,763	4,214	23,542	27,392	388	4,999	27,145	8,392	6,635	4,690	6,020	13,820	11,280	11,520	1,562	3,860	11,980
920	60	470	80	370	10	28	180	20	10	230	420	360	200	520	4,020	280	300	40	220	920
30		10		10							20	40	10							40
				30							20	10		20			40		20	20
	59	60	1	78	9	20	9	2	30	18	190	126	51	22	2			2	40	
	1			1	1	4	2			1								1		
10		1																		
		1					1													
20		90	20	30		20	80		20	40	70	80	20		20		40			40
		30	10	40						1		10			40		60		20	40
	121	181	39	165	72	74	66	20	54	136	38	273	256		160		20	40	80	
	40	126	10		2	11	15		21	7					15	2	77			20
			1	9							27	55	17		520	200	200	60	220	200
		7	1	10	5		3		1			13	21		20					
,975	8,181	27,513	9,632	16,841	4,467	23,852	27,907	451	5,196	27,670	9,524	8,089	5,499	6,926	19,423	11,888	12,697	1,706	4,640	14,288

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ON THE COLLECTION-NET USED IN THE CASE OF OBSERVATION OF D.S.L.

Junichi Ihara, Yoshio Yamaguchi and Keiziro Ozawa

(Received Jan. 25, 1956)

The results of the observation on D.S.L. during 1953–1954 are as follows. For the purpose of performing the observation concerning D.S.L. appeared in the sea off Yaizu fishing port in Shizuoka Prefecture, the design of the three kinds of new collecting-net had been made on the basis of experience of the previous observation. As a reference to design of these nets, the five kinds of model net were made which had been tested in the water tank at Tateyama Marine Laboratory of Tokyo University of Fisheries. From the test above, we have studied the condition of collecting-net which could be pulled along the middle layer of ocean. And on the basis of the results of the model experiments, three kinds of practical net have been manufactured.

This practical nets were used for the present observation, but we could not use satisfactorily, because of the lack of apparatus on researching-boat, Seityo-Maru. Concisely speaking, we could not collect the livings in the depth more than 150 meters, because the pulling-upward speed of the net was 0.6 m/sec by the winch machine of the ship and furthermore, the length of the wire of winch machine used was too short.

The construction of these practical nets are shown in Figs. 1–4.

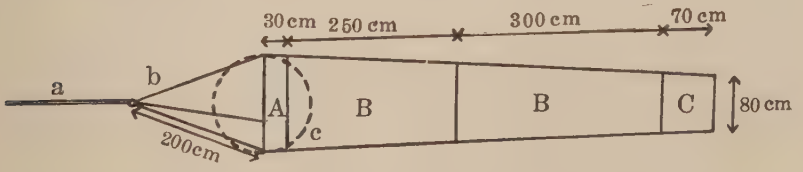

Fig. 1. Construction of collection net A. A, Heri-ami (Webbing net); B, Mi-ami (Trunk of net); C, Fukuro-ami (Bag net). a, Warp (Dia. 18 mm); b, Pendent (Wire rope. 16 mm); c, Iron hoop (Round 15 mm, Dia. 150 cm).

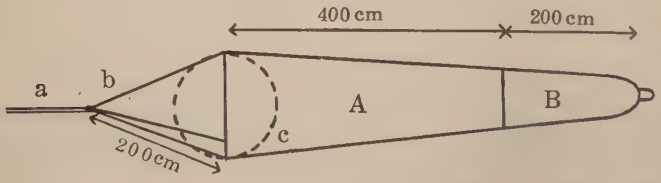

Fig. 2. Construction of collection-net B. A, Mi-ami (Trunk of net, knot-less net); B, Fukuro-ami (Bag net, knot-less net). a, Warp (Dia. 18 mm); b, Pendent (Wire rope 15 mm); c, Iron hoop (Round. 15 mm, Dia. 150 cm).

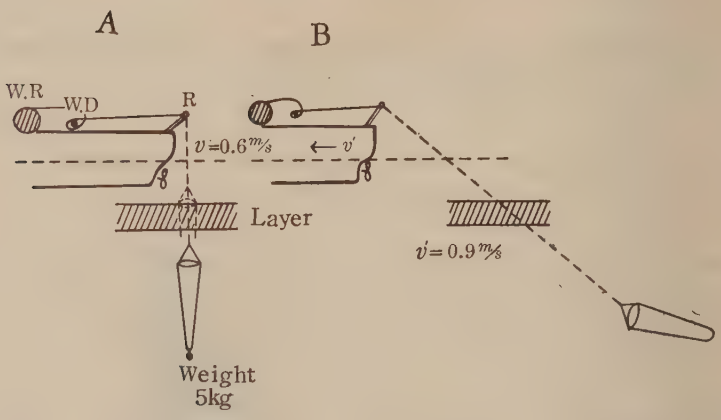

Fig. 3. Hauling method. A, Vertical hauling; B, Horizontal hauling; W. R, Wire reel; W. D, Winch drum; R, Roller.

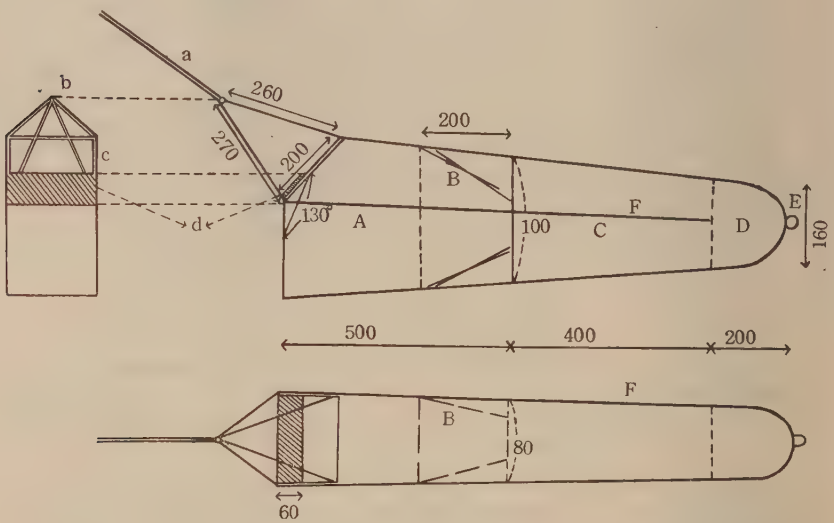

Fig. 4. Construction of collection-net C. A, Arate-ami (Large size mesh net); B, Flapper; C, Mi-ami (Trunk of net); D, Fukuro-ami (Knot-less net); E, Cod end; F, Lacing line. a, Warp (Dia. 18 mm); b, Pendent; c, Pipe frame; d, Board. All dimentions in cm.

The following table shows the biological data which were obtained by using A and B nets, at the time of the D.S.L. investigation in sea off Yaizu.

Referring to this table, it can be supposed that the appearance of D.S.L. is originated by the existence of Sergestes-shrimps (*Sergestes lucens* HANSEN) and Salpas in the layer. Namely, at the one station, we get many Sergestes-shrimps from the D.S.L. layer and also many Salpas at the many other stations from the D.S.L. layer.

Referring to the recording papers of fish-finder, it seems that the layer, in which the Salpas mainly exist, is relatively thick in the vertical width, but the trace of the layer on the paper is not apparently marked.

In this observation, the plankton-net was also used with together. But the samples of Sergestes-shrimp in the D.S.L. layer were caught only at the one station. Consequently, it is presumed that the species and volumes of samples collected will depend on the condition of the size of mesh, formation, towing-method and speed of the net used. (Refer the foot note.)

In order to research the phenomena of D.S.L. which may be caused by the livings in the water it is most necessary to collect the marine livings in the layer considered.

In spite of the fact that during the past two years, the collection of the livings was tried by various kinds of method, we could not yet develop the new adequate apparatus concerning the collection of livings on the basis of the experience of these observations.

Consequently, as it is very difficult to find the new apparatus suitable for our purpose: it seems that the application of the underwater-camera and television is aslo useful in the case of our observation.

But, fortunately, from the results of the observation in 1953–54, it is presumed that the phenomena of D.S.L. appeared in the sea off Yaizu in winter season is caused by the existence of Sergestes-shrimp and large type of zoo-plankton living with them. Therefore, referring to this presumption, in order to perform the more concise observation in the region of sea off Yaizu, the manufacture of the larger type of collecting net designed by us was ordered to the Rigosha Company.

The previous net did not satisfy the condition that we want to sample only the livings in a certain layer in the ocean. And, as illustrated in the case of the observation in 1953, the Sergestes-shrimp could not be almost caught by use of the plankton-net. Consequently, it is supposed that the swimming speed of Sergestes-shrimp will be quick. For the purpose of satisfying the condition above, the new-net was designed by considering the following three terms:

1) it must be suitable for the ability of the apparatus in the researching-boat.

2) it must be able to catch the livings in the D.S.L. layer which appeares in any depth of the ocean.

3) especially, it must be able to catch the Sergestes-shrimp and larger type of zooplankton.

The details on the design of net referred to above mentioned fact are as follows.

In the case of the operation of collecting-net, the ability of the previous winch is not suitable for our speed. Accordingly, the size of mesh and volume of the net (the radius of the entrance of net=1 m, the length of the net=2.85 m) were determined by considering the ability of Kelvin's Sounding Machine and the towing speed of the net (1 m/sec) to be adopted, and in order to satisfy the

Note: In our case, the towing speed of plankton net 2 m/sec, the towing speed of collection net 0.6–0.9 m/sec.

Table 1.

St. No.	Date Time	Position	Bottom Depth (m)	Depth and State of D.S.L.	Hauling method	Hauling speed m/sec	Catches	Remarks
1	1954–3 13th 18h–27m	34°–51.6′N 138°–21.2′E (off Yaizu)	150	60～80 m layer	Vertical hauling from sea bottom to surface	0.45	8 Sergestes-shrimps	A-net Bottom mud was found in the net
2	〃 〃 18–47	〃	150	Two layers; The upper layer was 15～20 m and lower layer was 50～70 m	Vertical hauling from 30 m depth to surface	0.6	10 Sergestes-shrimps and some Salpas	A-net
3	〃 〃 19–05	〃	80	The trace of recording papers of appearance of D.S.L. was thin, it was composed of three layers, upper was 15～20 m, middle was 50～70 m, lower was near the bottom	〃	0.6	15～16 Sergestes-shrimps about 12 mm in length	A-net locality of sampling near the Sergestes-shrimp fishing boat
4	〃 〃 19–25	〃	40		Towed horizontal to the bottom for 3 minutes, by slow speed, after engine stopped, the net towed vertically	0.9	1 Sergestes-shrimp, some Starfish, and some Salpas	A-net Bottom mud was found in the net
5	〃 〃 20–00	〃	170	50～100 m layer (Wide and thin on the record of fish-finder)	Vertical hauling from 120 m depth to surface	0.6	1 Sergestes-shrimp, and many Salpas	A-net
6	〃 14th 17–05	34°–51.0′N 138°–21.0′E (off Yaizu)	140	50～70 m layer	Vertical hauling from 130 m depth to surface	0.6	No Sergestes-shrimp and a few Salpas	B-net

7	17–20	〃	—	60 m layer	Vertical hauling from 80 m depth to surface	0.6	No Sergestes-shrimp and 30 ~40 Salpas	B-net
8	18–25	Yaizu L.H. on N82°W distance 2.6′ (off Yaizu)	—	140~150 m layer	Vertical hauling from 120 m depth to surface	0.6	Some Sergestes-shrimp and many Salpas	B-net Plankton—net was towed at 180~240 m depth and 1 Sergestes-shrimp was caught
9	19–05	34°-51.2′N 138°-22.0′E (off Yaizu)	246	120 m layer	〃	0.6	A few Sergestes-shrimps and some Salpas	B-net
10	20–18	off Yaizu	150		The length of warp was 80 m and towed 5 minutes, by slow speed, after engine stopped, the net towed vertically	0.9	No catch	B-net The form of net was unwell
11	20–45	34°-50.9′N 138°-21.3′E	150	40~60 m layer	The length of warp was 80 m and towed 3 minutes, by slow speed, after engine stopped, the net towed vertically	0.9	About 20 Sergestes-shrimps and some Salpas	B-net
21	21–13	〃	150	70~110 m layer	Vertical hauling from 120 m depth to surface	0.6	〃	B-net

condition that the sample only in the middle layer can be caught, the same type of operation-method as the closed net was adopted. The following design concerning our net was adopted with the object of satisfying the condition. The size of meshes of net which is suited for the collection of the samples in the D.S.L. layer can be selected by towing simultaneously with the nets having the difference of the size of meshes of net. Namely, the center of trunk of net is divided into two by dividing net, and the sizes of meshes of two parts divided are differed from each other, and in the respective part of two parts above the bag nets are equipped, and the bag nets can be easily replaced by another bag nets. The construction of collection net are shown in Fig. 5.

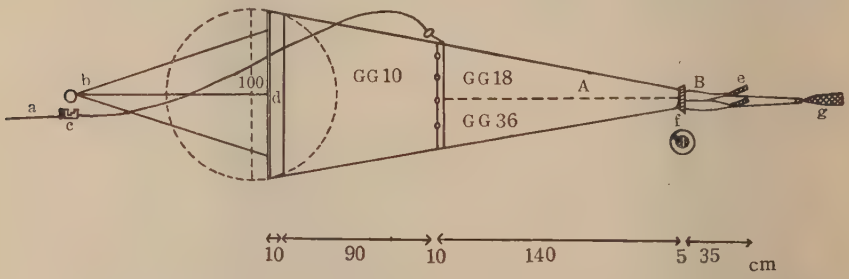

Fig. 5. Collection net. A, Shikiri-ami (Dividing net); B, Fukuro-ami (Bag net). a, Sounding wire; b, Pendent; c, Snapper; d, Canvas; e, Plankton collecter; f, Metal socket; g, Weight.

We adopt the following Müller-gauzes: GG. 36, GG. 18, GG. 10, XX. 5 as the materials of net, and GG. 72, GG. 36, XX. 7, XX. 13 as the materials of the four kinds of bag-net.

We have already finished the test of the operation concerning our collecting net in the sea off Yamaguchi prefecture. Accordingly, it is expected that the more concise observation on D.S.L. will be performed in the sea off Yaizu in the near future.

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THE SCATTERING LAYER IN RELATION TO FISHING

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According to the paper given by the many researchers, it has been suggested that, the cause of the scattering layer will be formed by the concentrated groups of the living organisms. From the biological point of view, this phenomenon is related directly or indirectly to the condition of fishing field and the favourable opportunity in the operation of fishings in all day long. It seems to be worth while to discuss, in the following, some of these observations having some relevance to fishings.

The vertical movements of fishes, which have something to do with the diurnal vertical migration of the scatttering layer.

On 3 July 1953, T. S. Umitaka-maru proceeding eastwards in the Bering Sea, about 200 miles north of Kiska Island, in a depth of about 4,000 meters, discovered a thick crowded fish shoals on the Echo Sounding trace. It is Alaska-pollack which were angled up by crew. They are shown in Fig. 1.

Fig. 1. Showing the movements of Alaska-pollack's shoals appeared on the echo sounding trace between 20h 15m and 20h 35m, on 4 July, 1953 in the Bering Sea.

At daytime, they were seen at 80–100 meters in the half way between depth of the sea. And they decreased their living depth as it became evening, and in the time-interval between from dusk to night, their living depth became the depth of 30 meters or less.

Salmons in the Northern Pacific and the Bering Sea, during the daytime, are caught in the depth of 20–40 meters by means of a long line, but at night, are entangled to the net drifting in the layer between the surface to only about meters.

Kinmedai (*Beryx splendens* Lowe), being landed on fishing ports along the coast of Sagami Bay, is caught by means of a angling line with 25–35 hooks

branched out, in the region of 300–600 meters in depth. The fishing operation above has been carried out in the daytime, but since some of fishing boats has been equipped with the fish finder, they has become to be able to operate the catch of fishes, not only in the daytime but in night.

The fish finder, a kind of the echo sounding device, plays the role of keeping a boat at a favourable field and getting the layer, which might be considered as the cause by planktons or the fishes feeding upon the planktons or a combination of these two kinds. At the Kimmedai decreases their inhabiting depth at night, particularly at dawn and dusk, the catch-operation has become more easy in the consequence of shortening the length of the angle line when to be paid out. Many Kimmedai has fed on the zooplankton and redish shrimp, which have been found out in the stomach of Kimmedai. This is an evidence to demonstrate practically the phenomena of the diurnal movements of the zooplankton and fish.

The scattering layer tends to appear in the central part of the circulating current.

In Dec. 1953 and Jan. 1954, T. S. Umitaka-Maru was anchored at Itō and the following experiments has been performed for the purpose of finding how the circulating current will influence for the distribution of marine livings. The current-observation was done by means of the drifting current-drags, on the top of which the microwave appliance-corner-reflectors were attached, and the movements of current drags were observed relatively on the rader scope. Simultaneously, the boat equipped with the fish finder ran about the Bay. According to the results obtained by this observation, it is presumed that by the action of the circulating current, namely the conpensative, circulating and slow coastal current, the marine biology will be permitted to concentrate toward the central part above has been known as the adequate field to have the large catches of squid, horse-mackerel, mackerel and others. There are some instances of the good fishing field concerning with the phenomena of scattering layer which is crowded with the tiny zooplanktons, namely ultimate source of food of all fishes.

The whaling field off Kinkazan, the mackerel fishing field south off Saishū Island, the serdine purse seining field off Uwazima, Ehime Pref. and off the western coast of Kyūshū Island corresponds to the instance mentioned above.

In summer 1953, on the way returning from the south sea region of Lat. N. 32°, the scattering layer has been observed on the echogram, but it may be difficult to estimate whether or not, the abandant distribution of tuna is directly related to this layer, because of the obsecurity of the behaviors of tuna itself.

Additional remark: The variation of the condition of scattering layer under the circumstances of the bright full moon changing its altitude, was observed in the evening on 24, Aug. 1953. When our ship were proceeding NNW wards at the position Lat. 27°–43′, Long. 146°–15′E, about 100 miles east of Ogasahara Islands, the existence of thick layer was estimated on the echo sounding trace of recording paper and it ascending steeply soon after the sunset.

The existence of layer was continued to be shown on the echo trace throughout the night, the vertical movements of the scattering layer and the altitudes of

the full moon in the time interval between 20h and midnight are shown in Fig. 2. While the moon's altitude was low, a thick condensed layer was appeared and as the time advanced, the higher the moon rose, the depth of the layer was

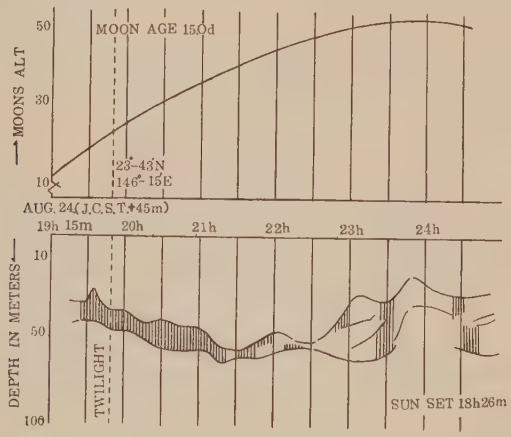

Fig. 2. Showing the scattering layer observations and the altitudes of the full moon between 20h and midnight on 24 Aug. 1953, when proceeding 307° on her cource in position 28°N, 146°E.

increased. After the moon had risen more than 40° of its altitude, the condition of the layer became erratic and scattering. The weather condition was fine and the sea was smooth. From this observation, it is expected that the light-intensity will give the constitution of the scattering layer or the individual elements contained in the constitution some influences.

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RELATION OF THE DSL TO WATER TEMPERATURE AND ILLUMINATION

Tadayoshi Sasaki, Seiichi Watanabe, Gohachiro Ōshiba and Noboru Okami

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I. Introduction

Although the problem of the DSL has been receiving considerable attention, there has been no definite conclusion on the source of the layer yet. Most of the investigations have been carried out under the indefinite assumption that plankton is responsible for an echo in the sea.

In the present observation, as a part of the cooperative investigation on the DSL, some physical natures (mainly underwater illumination and temperature) of the layer were measured accurately by means of specially designed apparatuses.

For the measurement of the illumination, the underwater photometer with a photomultiplier[1] described in the previous paper was used. Vertical distribution of water temperature was observed by means of an automatic temperature-depth recorder of "KAKEN" type[2] and a thermistor thermometer made in our laboratory.

II. Result and Discussion

1. Correlation between the DSL and water temperature.

Vertical distributions of the water temperature were measured with an automatic recorder at two places where the DSL could be observed, i.e., in Tateyama Bay, Oct. 1953 and Sagami Bay, Mar. 1954. In both cases it was observed that the water temperature was reversed at a certain layer between the surfacc and the first scattering layer. Owing to the lack of data, the relation of the temperature reversing layer to the DSL is not definitely established and further observation of the temperature is necessary to solve the problem.

2. Correlation between the DSL and underwater illumination.

The scattering layer is usually confined to deep water, and the observation of illumination in this region is quite difficult. H. B. Moore[3] has calculated from the data obtained previously by several authors the iso-illumination curves of the sea where the DSL was observed, and found a correlation between the diurnal movement of the curves and that of the layer. In the present case, in Tateyama Bay, as the DSL appeared in comparatively shallow water, the illumination could be measured directly by means of a photometer which is available down to a depth 100 m. The correlation between the iso-illumination curves thus obtained and the movement of the DSL which appeared in the echogram was studied.

Fig. 1 shows the iso-illumination curves obtained in Tateyama Bay during

06:00–08:00, Oct. 19, 1954. An arbitrary value of 100 is taken for the intensity of the illumination measured at the depth 4 m at 08:00. The curves shown in Fig. 2 were obtained during 15:30–17:10 on the same day. In this figure an arbitrary value of 100 is also taken for the illumination at the depth 4 m at 15:30. As seen from Fig. 1, the curves show some anomaly during

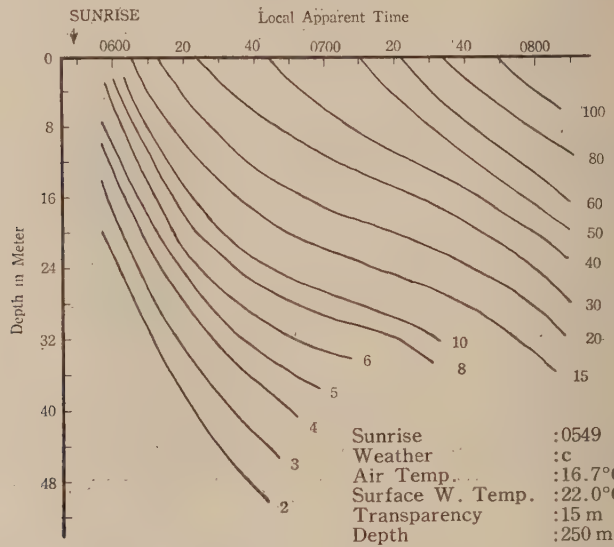

Fig 1. Iso-illumination curves obtained after sunrise. Oct. 19, 1954: Tateyama Bay.

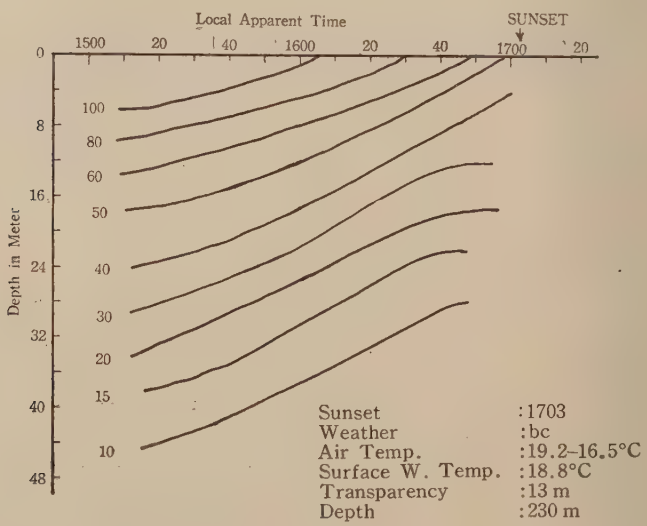

Fig. 2. Iso-illumination curves obtained before sunset. Oct. 19, 1954; Tateyama Bay.

06:30–07:10. The same is true for the curves in Fig. 2 obtained about sunset. Putting aside the source of the anomaly, if it is assumed that the DSL ascends or descends along the iso-illumination curves, a change of velocity of ascent or descent of the layer must be observed at the same time when the anomaly appears on the curves. From this point of view, for the purpose of elucidating the nature of this anomaly, another observation was made in Suruga Bay, March 1955. In this case, instead of obtaining the iso-illumination curves, the illumination at the depth 70 m was measured every one minute. As shown in Fig. 3, the rate of increase of illumination decreased during 06:10–06:30. It is clearly seen from the data obtained at the same time by a deck-photometer (doted line in the figure) that the phenomenon has no relation to the cloudiness of the sky. On the other hand, the DSL appeared in the echogram at the depth of about 220 m before and after sunrise descended monotonously till about 06:15 and the rate of descent of the layer during 06:15–06:30 is smaller than that observed before and after that interval, i.e., this anomaly observed for the DSL fairly coincides with that observed for the iso-illumination curves.

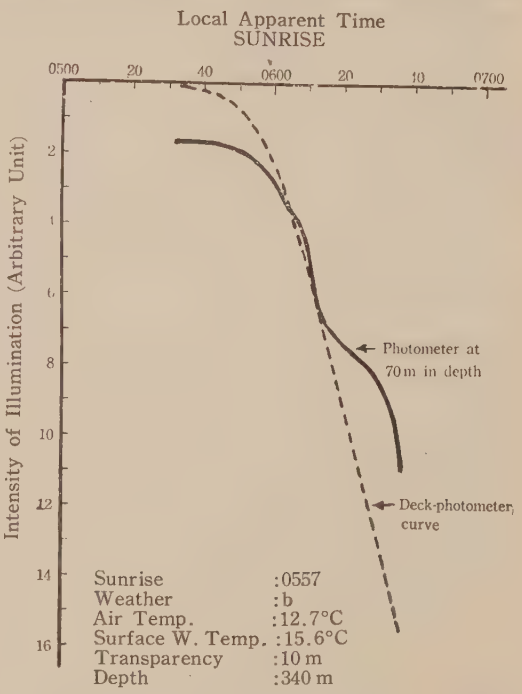

Fig. 3. Variation of illumination at the depth of 70 m obtained before and after sunrise. March 17, 1955; Suruga Bay (35°–02.9′N, 138°–33.6′E).

There still remains a question whether this anomaly of the iso-illumination curves appears only in the sea where the DSL is observed in the echogram. In the present state, owing to the lack of data, definite conclusion has not yet been made, but it seems quite plausible that the scattering layer has some relation to the organism which ascends or descends according to the illumination in the sea.

Photographing of the DSL was also tried at the same time by means of an underwater camera of "KAKEN" type, but definite result could not be obtained so far as the present mechanism was used. Further studies on the light source and the mechanism for close-up photographing are necessary to take the clear pictures of the layer.

In Suruga Bay, March 1955, an observation using an underwater television camera was also attempted, but unfortunately, this observation could not be successfully carried out because of bad weather.

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A STUDY ON THE VISIBLE FIGURES OF THE BOTTOM WHICH RESEMBLES TO THAT OF SO CALLED D.S.L.

Hiroshi Niino and Keijiro Ozawa

(Received Jan. 25, 1956)

If one examine carefully the record of fathogram, it remarks that in some figures, there are two or three stripes run under the bottom line just like as so called D.S.L. in the water. The author obtained several examples of such a kind of peculiar record of the bottom at the time of voyage around Kyushu in the year 1948 by the training ship Shinyomaru. The noticeable figures in the record of the bottom are obtained between Shimonoseki and Ube coal mine, west Inland Sea and also at the coast of gulf of Tachibana, east Nagasaki prefecture. Both regions are shallow inland sea and the bottom character are muddy one.

An interrogation point is that which one of the stripes in the figure shows an accurate surface plane of the sea bottom. Unfortunately, the detail survey on the bottom deposit or the bottom water did not carry out at the time of record.

Along the coast of the regions where Shinyomaru passed through, there developes Tertiary system in the foundation and Pleistocene system lies unconformably on Tertiary system.

It seems that the surface of the sea bottom covered by recent deposit (sand or mud), under this layer lies Pleistocene or Tertiary system. In the following examples, it seems that the visible stripes in the bottom figures show a boundary of the geological formation or the different hardness of the strata, because the sound wave reflact at the boundary plane according to the rate of the consolidation of the sediment which are proportioned to geological age.

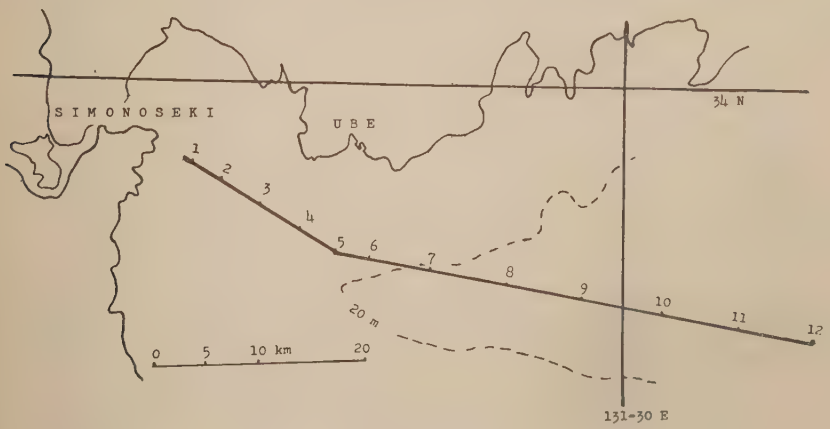

Fig. 1. Line of record between Shimonoseki and Ube.

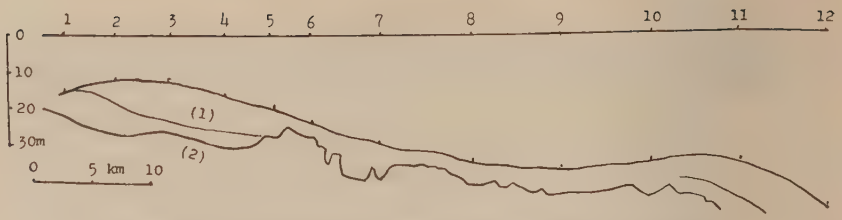

Fig. 2. Visible Stripes under the surface of sea bottom.

The record of sea bottom from Shimonoseki to Ube coal mine. (Figs. 1, 2) In the figures of the record, there are two visible stripes under the surface of the sea bottom. The lowest stripe runs very irregulary, at St. 5, it elevated near the surface of the bottom. This station is located on the elevation of the basement Tertiary rocks which determined by the record of the seismic observation and also by the stratigraphy in the gallary of coal mine. At St. 6–7 this line depressed downward abruptly about 10 m. This position is located closely at the fault line which observed by seismic survey and stratigraphy in the gallary of coal mine.

The record of the bottom along west coast of Tachibana Bay, east Nagasaki (Figs. 3, 4, 5, 6). Two stripes are shown under the surface of the sea bottom. These two line seems to express the boundary of Recent deposit, Pleistocene and Tertiary rocks. At the coastal region of this district, there develop Tertiary coal

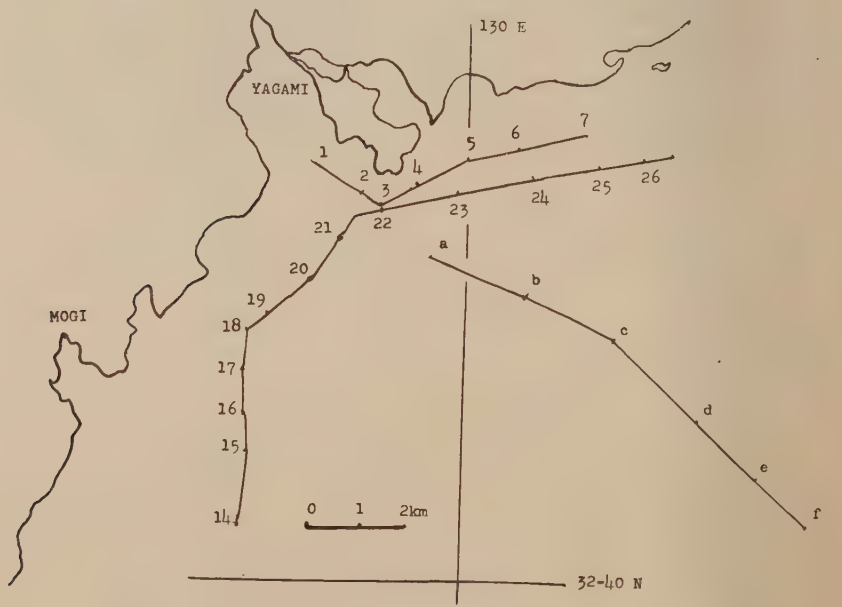

Fig. 3. Line of record at Tachibana Bay, East Nagasaki Prefecture.

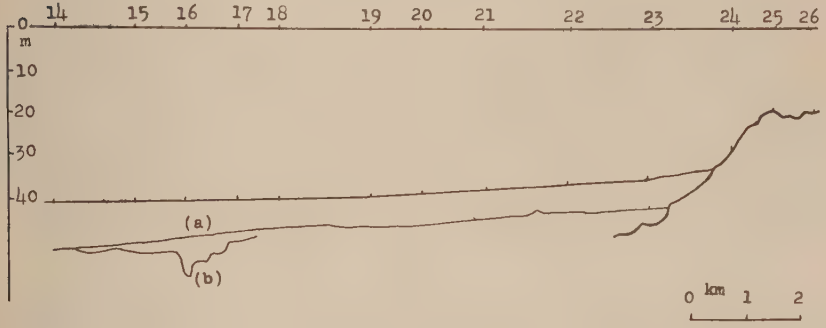

Fig. 4. Visible Stripes under the surface of sea bottom.

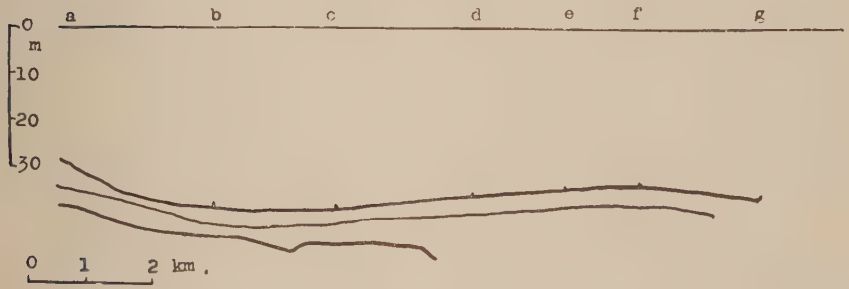

Fig. 5. Visible Stripes under the surface of sea bottom at Tachibana Bay, record line runs from coast to the opening.

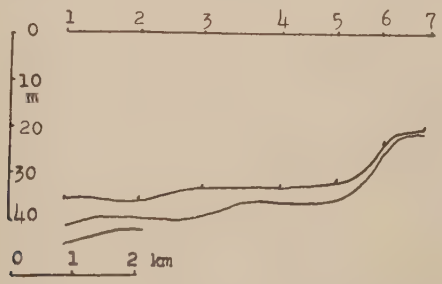

Fig. 6. Visible Stripes under the surface of sea bottom at Tachibana Bay, record line runs along near the coast.

bearing strate which covered by Pleistocene marine deposit. In the figure 4, a narrow deep depression of line existed on the lower most strip. This figure resembles a cross-section of a valley in the foundation which were buried by the deposit of the next geological age.

The record of the sea bottom crossed right angle to the coast of Tachibana Bay. (Fig. 6)

The surface layer (Recent deposit: sand, mud, etc.) goes on increasing in thickness for openings.

It is an interesting problems that in the figure of the record of sea bottom by fathogram, there notice a visible figure like as D.S.L. in the water. Perhaps it means the boundary of the deposit in the bottom materials, some scientist calculated the thickness of each layers. But if a dense muddy water lies close to the bottom, it is a question how is the figure of the record in fathogram. This question may be solve by the detail survey and experiment in the feature.

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GENERAL RESULTS OF THE OCEANOGRAPHIC SURVEYS (1952–1955) ON THE FISHING GROUNDS IN RELATION TO THE SCATTERING LAYER

M. Uda, N. Watanabe and M. Ishino

(Received Jan. 25, 1956)

1. Result of the 1st Survey (19–29, Aug. 1952 by Umitaka-Maru).

Blessed fine weather continued in the period it has brought plenty harvest to us. We observed bottom depth (by echo-sounding), bottom character (by dredge), water temperature (by reversing thermometer and electric recording thermometer), salinity (determined by Mohr's Chlorine titration method in the Tōkai Regional Fisheries Research Laboratory), dissolved oxygen, nutrient salts (phosphate and silicate), pH, currents, color of the sea and transparency, wind-waves and swell, meteorological elements (air temp., atmos. pressure, wind, humidity, cloud, weather etc.) below to the maximum depth of 1000 m in the coverage (Kumano-Nada~Zunan Sea-Region~Off Kinkazan) amounting to 30 stations. (See Fig. 1. p. 103).

During the period the Kurosiwo Current flowing with a velocity of 1–3 knot through the section between Niizima and Hatizyō Is. in northeasterly direction, and entering in the NE-Sea Region with a velocity of about 1 knot or more which corresponds to the mixed extension of Oyasiwo Current within 50 sea-miles off Kinkazan.

There we see the boundary of both warm and cold watermasses and eddy currents with the abrupt change of the surface water temperature from 20°C to 29°C. (Intermediate Water of Oyasiwo Origin, E. 20–80 SM. off Kinkazan 4°C–6°C).

The localities at each oceanographic station were fixed by means of Loran, Radar and astronomical star-fix method with high accuracy.

We have observed and sketched remarkable current-rips by means of Radar south off Mikura-zima, and east off Kinkazan.

(i) On 21. Aug. at 18.30 (nearly sunset), at SE 20 SM Off Daiō-Zaki we observed an ascending DSL and sampled red-shrimps with copepods by net hauled up from the 400 m. to 50 m. depth, where corresponds to the upwelling region (showing water temp. 15°C. at 100 m., 11.6°C at 200 m., 9.7°C at 400 m.)

(ii) On 22. Aug. in evening twilight a faint DSL appeared near the bottom of Kanminato, Hatizyo Is. and continued to 21h.

(iii) On 23. Aug. at 19.30 around a Shinkurose Bank (Skipjack fishing-ground) between Mikurazima and Hatizyo Is. a DSL like echo-trace somewhat ambiguous was found at the level of 50–60 m. depth and descended to the level of 76–86 m. depth at 20.10.

(iv) On 25. Aug. at 18.16 (civil twilight) east off Hukusima (bottom depth 240 m), lying near the shelf-edge in the mid-depth at the level of 30–70 m. (water temp. 20°C–11°C) DSL appeared.

In its every near south region we have seen the boats fishing marlin and trawling i.e. the fishing grounds on the shelf-edge.

(v) On 27. Aug. in the early morning 4h–5h (day-break twilight up to sunrise) 120 SM. E. off Kinkazan, a DSL was detected at about 4 o'clock at the level of depths 26–60 m. (17°–11°C).

(vi) On 28. Aug. at twilight 03.15, 13.5 SM. E off Kinkazan a considerably dense echo-trace of DSL at the level above the 160 m. depth was found, which descended down to the sea-bottom outside of the shelf at about 03.20 (water temp. 11.5°C at 100 m, 7.5°C at 200 m. depth).

2. Result of the 2nd Survey (1952) in the Suruga Bay (Seicho-Maru on 10–15. Sept.).

Since it was out of season and the spent period of Sergestes-shrimp in the bay, the period was unsuitable to detect the shrimp school, and moreover the continued gales interrupted our survey. The cruise was unsuccessful.

(i) On 10. Sept. from 15.00 off Numadu in Suruga Bay a DSL-like echo-trace was found at the mid-depth of 120–130 m., which ascended to 25 m. depth at 15.23 (plankton sampled.).

(ii) On 11. Sept. near the shelf-edge south off. Mihogazaki (E. of Kunō-zan) at 05.25 DSL appeared at the level of 40 m. (sea-bottom 200 m. depth) and descended to 80 m. depth at 05.50, and to 100 m depth (bottom 300 m.) at 06.00 (sunrise at 05.30). (Water temperature range 20°C–15°C).

The speed of DSL descent was 60 m/35 min. ≒ 3 cm/s.

(iii) On 11. Sept. at 13.40 off Ōsaki~Ōsezaki in Suruga Bay a DSL was detected at the level of 210 m. depth (sea bottom 260 m. depth) and the corresponding water temperature above 13°C. At 11.30 on the same day we found a fish school of bonito near the line of convergence with white-caps of current-rips and there caught 30 fishes by tow-line-angling.

3. Result of the 3rd Survey in Inland Sea and other Coastal Waters (by Umitaka-Maru) on 2–16 Dec. 1952.

(i) In Beppu Bay. On 4. Dec. about 10 minutes after sunset at 17.00 DSL appeared, then at 17.30 lying at the level of 40 m. depth (bottom 46 m.). and at 18.20 ascended to the level (20–40 m. depth-surface) with the ascending speed 40 m/100 min. ≒ 0.7 cm/s. and the corresponding water temperature of about 18°C in upper homothermal layer.

In the next morning about at 05.30 it faded away any disappeared.

(ii) In Beppu Bay on 5. Dec. after sunset about 19.00, we remarked nearly 115 squid-fishing-boats operating in the fishing ground where corresponds to the conspicuous upwelling along the steeply-inclined slope of sea bottom (50–70 m. depth) aroused by the NW-prevailing monsoon. (See Fig. 2, p. 108)

There we found DSL in the astrnomical twilight (17.36–18.35), at 17.41 appearing at the level of 20–55 m. depth, and gradually changing into denser concentration with the eddy-like turbulent pattern of its upper edge, at 18.00–18.10

almost ascended to the topmost layer and represented a very densely concentrated echo-trace. (the speed of ascent computed is 25 m/40 min. ≒1 cm/sec.) DSL began to diffuse away from the time about 00.50 and then separated in double layer with the sudden cloudiness. DSL disappeared at 03.36 (1 hour before the moon-transit, moon-rise at 20.14 on 6. Dec.)

(iii) On 7. Dec. in Bungo Strait, the sea was rough due to the prevailing northers. In the night we have undertaken the survey in the sardine-fishing ground in Sukumo Bay where 60 purse-seine boats operated with the total catch of sardine 7500–1500 kg. wt.

Notwithstanding our effort to find DSL during the cruise from Tosa Bay (8–9. Dec.), through Kii-Suidō (11. Dec.), Enshū-Nada (12. Dec.) to Sagami Bay (13. Dec.), on the shelf-edge, and on sea-valley and banks, we have detected none of DSL, probably due to the continued rough sea by the persistent NE strong gale during the period.

4. Result of the 4th Survey by Umitaka-Maru (7–20 Feb. 1953).

At first we intended to carry out the survey on the tuna fishing grounds in the Equatorial Pacific, and navigating to south near Ogasawara, we were obliged to return due to the sudden patient in our crew and to change our schedule.

From 12. to 20. Feb. we took the survey in Sagami Bay, Suruga Bay, the adjacent seas of Chiba Pref. and of the Idu Islands.

(i) Day by day during the persistent gales of the severe westerly monsoon or northeasterly gales, the branches of warm current (Kurosiwo) invades in the eastern part of the bays (Sagami Bay, Suruga Bay) and the colder coastal water in the western part of the bays. In the western part of the Sagami Bay during the season from 7 Dec. to 17 Dec. abundant catches of yellow-tail in coincidence with the invasion of the rapid onshore current in westerly or southwesterly direction were reported. In spite of the remarkable abundance of phyto-plankton in the western region (Odawara～Manaduru～Hasima) we have not observed DSL, however, the echo-traces showing yellow-tail like large-sized fishes hitherto observed.

In that period we have inspected the mackerel fishing boats operating in nights with fish-lamps at the localities east 1 SM. off Niizima, near off Katsuura Light House, and off Kamogawa in Chiba Pref.

(ii) On 14. Feb., Off C. Hagatizaki on east of Suruga Bay DSL appeared at 22.15 in the layer of the 125–160 m. depth (bottom depth 380 m.) and at 23.00 after ascending to the depth 90–130 m. it disappeared, where rich harvest of macro- and micro-zooplankton sampled (water temperature about 14.3°C).

(iii) On 15 Feb., off Arare in the Suruga Bay at about 00.55 we found a DSL at the level of 90–120 m. depths (bottom 560 m, water temp. 14.2°C).

(iv) On 15. Feb., off Numadu in the Suruga Bay, from 06.30 before sunrise (06.41) to 07.00 descending DSL from the 145 m. depth to the 400 m depth was found, (sea bottom 570 m., water temp. 14°–10°C).

(v) On 15 Feb. off Kanbara in the level from 20 m. to 150 m. depths (densest trace at 140 m. depth) and at 05.45 it descended to the level of 160 m. depth (bottom depth 600 m., water temp. 13.8°C).

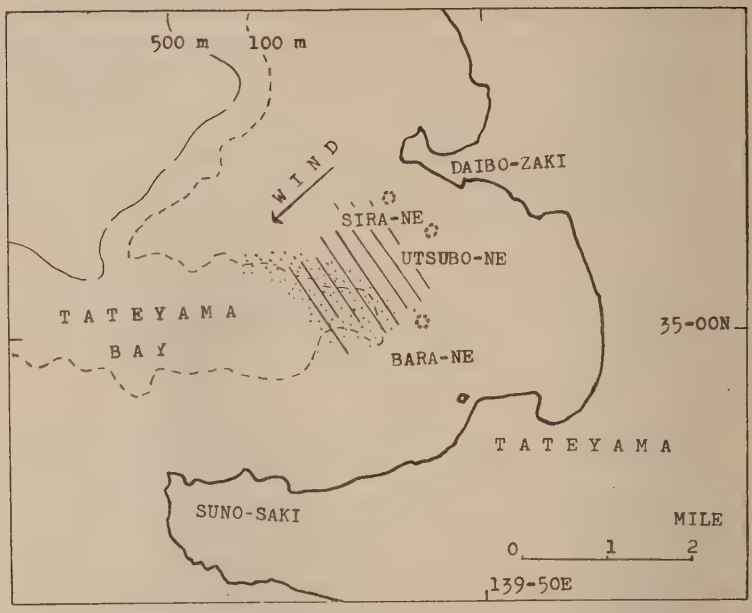

Fig. 1. Fishing ground and DSL surveyed in Tateyama Bay. (hatched area—DSL, dotted area—Mackerel fishing ground.)

5. Result of the Survey in the Mackerel Fishing Ground in the Tateyama Bay (Autumn, 1953). (See Fig. 1).

The survey made by 2 echosounders (R. 24 kc, Nihon Denki 50 kc) on boards of Seicho-Maru and Sitigōtei, both training boats belonging to the Tōkyō University of Fisheries, at the entrance of the Tōkyō Bay and in the Tateyama Bay during the period 24–26, Oct. 1953. On the morning of 25. Oct. corresponding to moon age 17th too bright moon light presumably had diffused SL. (Scattering Layer).

In the evening of that day SL appeared at 15.50 in the layer of 24–34 m. depth at the station near the shelf-edge on the head of sea-valley at N 35°E off Dai-bōzaki in the Tateyama Bay, in coincidence with the thermocline at the 24–28 m depths (above the 20 m depth water temp. 22°C and at the 40 m depth 19°C), and it ascended to the surface layer above the 12 m depth at 16.15 (where the echo-trace of fishes was seen near the bottom of 50 m. depth in thickness of 5 m.)

After sunrise about at 16.55 a fleet of fishing boats assembled on the Yokose-bank (or Yoko-Ne) the shelf-edge corresponding to the maximum curvature of the 200 m. isobathymetrical contours and began to operate mackerel-fishing with fish-lamps, where at 17.15 DSL found at the level from 9 to 26 m. depths broadly around the fishing bank, and at 17.46 it ascended near to the surface layer.

At that time by the strong NE-E wind blowing with the velocity amounting to 10 m/s a remarkable upwelling near the mackerel-fishing ground in question located on the shelf-edge was observed. (With the observed transparency 14–16

m., color of the sea 4–5, in the waters adjacent to the coastal front DSL shows the indicator for mackerel-fishing ground.)

On next morning (26. Oct.) the catches from above fishing ground landed on Hunagata Harbour, i.e. Masaba (Pacific mackerel, body wt. 450–750–1000 g.) of 7500 kg. wt. and Azi (Horse-mackerel) of 1000–1250 kg. wt. were shown before us in the fish-market.

6. Result of the Survey in the *Sergestes*-shrimp (*Sergestes lucens Hansen*) Fishing Ground off Yaizu in the Suruga Bay (Mar. 1954) on Board of Seicho-Maru.

On 12. Mar. We left Shimidu Harbour at 15.00 (See Fig. 2), through southerly swell and northeasterly strong wind arrived at Yaidu fishing ground at about 18.30 after sunset, when DSL finished its ascent already and at about 20h. showing slight echo-trace and then it faded away.

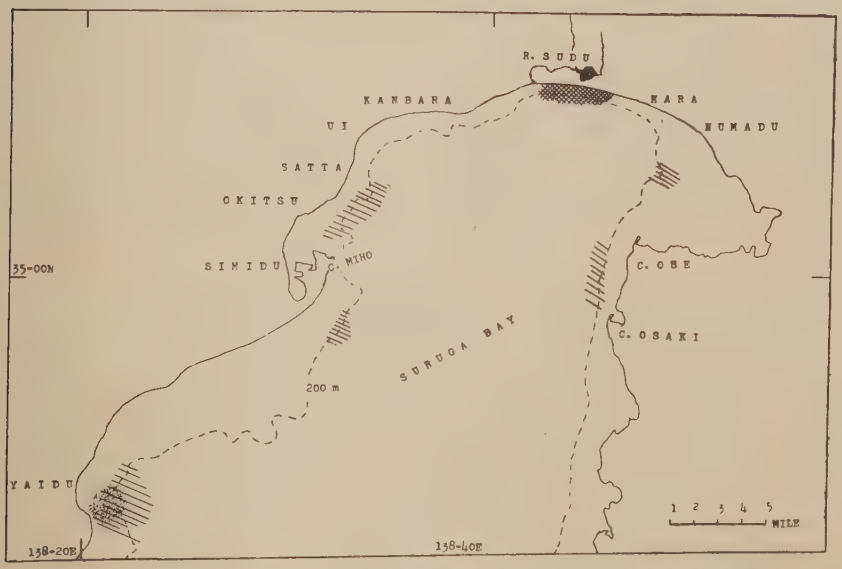

Fig. 2. Fishing ground and DSL surveyed in Suruga Bay. (hatched area—DSL, dotted area—*Sergestes*-shrimp fishing ground, cross line area—Polluted water region.)

In that night we carried out our observation exposing ourself to the cold NE gale and got the optimum water temperature (15°C–16°C) about the 25 m. depth for *Sergestes*-shrimp fishing by several tens fishing boats (the average catch per one set of boats in all night amounted to 260–380 kg. wt.).

On 13. Mar. at 04.45 (twilight) DSL found at the 40 m. depth not so apparent because by the effect of moon light. In the evening dusk when DSL appeared

and began to ascend, we at once tried net sampling and caught *Sergestes*-shrimps in the DSL.

At 17.50 below the prescribed DSL another slight DSL appeared as stationary one where we got some salpa by towing-net. DSL located at 80 m. depth (bottom depth 140 m.), at 18.15 in the level of 60–80 m. and at 18.30 separated into layers for the 15–35 m. depth and the 50–70 m. depth. With regards to the upper DSL (above 25 m. depth in the shallow region of bottom depth 30 m.) We sampled by plankton-net towing from 30 m. to 0 m. and got *Sergestes*-shrimps. At 20.05 the lower DSL descended to 70–120 m. depth and the upper one faded away, probably because by the increase of moon light (half moon transit). (At 20.25 shrimp and abundant salpa caught by net).

The shrimp-fishing ground in question with the bottom depths of 30–200 m. located at the pocket-like shelf-edge having steepest slope where the 200–800 m. isobathymetric contours most closed to the coast and the complicated bottom configuration shown by echogram. (See Fig. 2). By the prevailing westerly winter monsoon upwelling may be especially strengthened on such topographical conditions off Yaidu and may lead such most favourable *Sergestes*-shrimp fishing-ground off Yaidu in the Suruga Bay in winter. Of course other factors constituting *Sergestes*-shrimp fishing-ground are considered to be the eddy-current near the estuaries (mouths of Abe River, Seto River) in the coastal water having lower salinity and turbidity (transparency below 5 m., color of the sea above 7) closed to the coastal front and the optimum water temperature 15–16°C (at the depth of 100 m. upwelled cold water), the rich zoo-plankton in the vicinity to whom the shrimp school attracted for feeding and following them migrated vertically.

During its ascent and descent DSL tends relatively denser and after arriving its top-most it faded away.

(i) In the evening ascent DSL increased relatively its denseness and after darkening attained to the top-most layer it diffused gradually and faded away.

(ii) It is our problem, to find the mechanism, how the scatterers constituting the scattering layer concentrated, we can point out submarine illumination and water temperature (especially thermocline) as the most important factors. On 17–18 Mar. 1954 we have proved the ascent and descent of DSL some definite iso-illumination curve in submarine waters.

(iii) On 14 Mar. evening at 16.15–16.30 in the *Sergestes*-shrimp fishing ground off Yaidu a faint DSL appeared and gradually ascended to the level of 50–60 m. depth at 16.42. (net sampling made.). At 17.50 when southerly tidal current turned to northerly current, at just moment with the sunset several tens fishing-boats for shrimp-fishing left Yaidu Harbor and rushed to the fishing ground, showing a curious coincidence of the ascending behaviour (the 2nd DSL) of the shrimps in underwater. Probably it may be due to the fishermen's experience in long years.

The upper edge of second DSL-trace ascended clearly from the level of the 140–150 m. depth at 18.10 to the level of the 130–100 m. depth at 18.12, the 120–190 m. depth at 18.24., and at the 40–60 m. depth at 20.40 where a plenty of zoo-

plankton (Calanus etc.) by towing plankton net and about 20 individuals of *Sergestes*-shrimp by towing larval net were sampled.

In this way we found the principal nature of the scatterers made of *Sergestes*-shrimps mingled by zoo-plankton (copepods etc.) in the *Sergestes*-shrimp fishing-ground off Yaidu.

The catch in the above one night amounted to 9000 kan (3.4 ton wt., price 9000×800¥=7.2 million ¥) by 60 sets of boats and 100–200 kan (375–750 kg.) per one set-boat.

7. Result of Survey in the *Sergestes*-shrimp Fishing Ground in the Inner-most Region of Suruga Bay in Winter.

On 15. Mar. blessed by fine weather we took the survey along the coast west to Haramachi in the northern Suruga Bay where the most prosperous *Sergestes*-shrimp fishing-ground in the past times of thirty of forty years ago (Taisyō-Era) which might declined by the pollution of the discharged waters from industrial factories including a hundred pulp-paper manufacturing factories. (See Fig. 2)

At first we cruised offshore to east and obtained a rich crop of macro-plankton by net haul several miles off Yui (one of the old famous fishing ground with a hope to the *Sergestes*-shrimp fishery in this region in near future).

However, approaching to the coast near the estuary of Suzu-River from Fuji-Mae, off Ueta to Tago no-Ura, by mere visual observation a belt of brownish polluted water with bad smell extending within 0.6 sea-mile from the coast was found.

Such a clear line of demarkation against the offshore greenish water may be traced every day by aircraft inspection or aerial photographic survey. On our echogram a peculiar echo-trace reflecting from the scattering layer near to the remarkable pollution by some fiberous matter. On 15. Mar. in evening from the time before sunset to 19.00 in the *Sergestes*-shrimp fishing ground (before fishing season) off Satta-Pass west to Yui, a faint DSL was observed during the time 1820–1822 at the depth of 30–40 m., at 18.48 at the 80–90 m. depth. Since by net sampling only "Tane-kurage" (a kind of salpa) was obtained, we concluded consequently that the shrimp is too early to be fished in this period.

8. Result of Survey in the Yellow-tail Fishing Ground in the Sagami Bay.

On 17. Mar. we took surveys at about 16h. in the sea near the yellow-tail set-net ground of Itō (Arai) and at 17h. in the sea near Aziro (Koami) set net ground where just the evening fishing with the catch of yellow-tail 700 individuals and leaping of fishes on the sea-surface were seen. At the both fishing grounds lying near the shelf-edge of about 100 fathoms line we observed comparatively transparent coastal water of transparency 14 m. and color of the sea 4 in Forel's number. (See Fig. 3)

Fig. 3. Fishing grounds (Set-net) and DSL surveyed in the Western Sagami Bay. (hatched area—DSL.)

From 17.25 moving spotty echo-traces in DSL (A) found at the level of 40–50 m. depth (in coincidence of the migration layer) were identified by us as those of yellow-tail shoal because which were resembled to those of albacore or skipjack at Ogasawara-Uracus Ground obtained by Umigata-Maru and to those of yellow-tails in the set-net exhibited by the Aziro-Fisheries Assoc. Then we tried to take photograph repeatedly by the underwater camera (Kaken) in the DSL (A) appeared, but caught only the image of circular planktons on film not the image of yellow-tail (probably restricted by the short focus-length 1 m.). We tried angling to catch the fish, but it ended unsuccessfully.

Another DSL (B) (supposed to be constituted by concentrated layer at 18.30 at the level of 35 m. depth and at 18.32 ascended to the 20–30 m. depth. The former DSL (A) ascended also gradually from evening to night (18.40–19.36).

On 18. Mar. early morning off Aziro (Koami) at 05.10 we observed the appearance of DSL in the levels 40–130 m. depth and at 05.20 a distinct DSL separated from the surface layer began to descend and located at the level of 40 m. depth at 05.37, and to the 50 m. depth at 05.39, 60 m. depth at 05.44 (bottom depth 320 m) at depth 80 m. at 05.53 (bottom 300 m.) with the speed of descent

80 m/30 min. 4.4 cm/s., and at about sunset it diffused away such as at 06.20 to the 80–160 m. depth, (bottom 300 m.), at 06.30 to the levels of 50–240 m depth.

Following the descent of DSL, photography by the underwater camera and net-sampling with other oceanographic observations were conducted successively. The planktons (zoo- and phyto-both) sampled were very rich at this station.

The water temperature in the upper 50 m. layer was 15.3°–15.5°C, the optimum one for yellow-tail migration and at the 100 m. depth 14.5°C (12.5°C at 150 m). On 18. Mar. evening we surveyed the Kawana yellow-tail set-net ground and found the ascent of DSL at the depths of 40–50 m at 17.55, 30–40 m at 18.17 (bottom depth about 50 m.).

Experiments were made in order to find the reflection of ultrasonic wave by the falling sand-particles thrown in the sea from the board of our ship with the result of scattering echo-trace to the depth of 20–30 m and the reflection by the body of yellow-tail (2.5 kan wt.) suspended in the submarine water with the proof of the echo below to the depth of about 30 m clearly.

9. Result of Survey in the Mackerel Fishing Ground in the Tateyama Bay (Autumn, 1954).

On boards of Umitaka-Maru and Sitigō-Tei the echosounders used are F 50 A type (200 kc) and the Fishing Boat Laboratory type (24 kc). On 17. Oct. early morning at 4h, we approached to the fishing boats operating with fish-lamps within the cold northerly wind.

In twilight from 0423 to sunrise at 0547 we could not find DSL on 17th, at 1550 at the entrance of the bay (0.8 km south off Sirane-Bank) DSL-like echo-trace was found at the 350–360 m. depth (bottom depth 420 m.) which shows the level of DSL in the daytime.

During the evening twilight 17.05 (sunset) 18.34 scattered echo-trace representing fishes appeared, at the level of 70 m. depth. At 18.05 cruising to the shallower (bottom depth 46 m), we observed DSL which at the level of 20–40 m, depth appeared and diffused to the upper layer at 18.14.

Off C. Daibō-zaki (South of Sirane-Bank, 56.1°, 1 SM. off Suzume-Is.) during our observation from 18.43 to 20.00 DSL continued in somewhat stormy rough sea (NNE wind amounting to 15 m/s, 19.20 beginning to rain. In that night cyclone passed over).

Since on 18. Oct. raining and at the entrance of the bay yet the strong northers continued with the speed of 10–11 m/s and high waves, we made surveys (current 222°, 0.34 Knot) near Sirane-Bank adjoining to the shore, and found the appearance of DSL at dusk hour 17.00–17.10 (evening twilight from 17.04 at sunset to 18.34) at the level of 60–80 m. depth.

At 18.10 DSL south off Sirane (bottom depth 65 m) ascended to the depth of 40–60 m. and changed to the spotty echo-trace of fish (mackerel ?)-shoal. We continued observations and sampling to 20.30. On the morning (04.00–09.00) of 19. Oct. We observed currents in the bay (0.9 knot in the direction of 198°) near Sinane, but found none of DSL.

On the afternoon of that day after the hydrographic observation (currents

during 15.23–16.21, 0.33 knot in the direction of 212°, wind NNE 4) in the center of the bay (bottom depth 360 m.) near the station approximately the same to the mackerel fishing ground on 17. Oct.

We found DSL at the level of 320 m. depth before sunset (17.03) and sampled several small shrimps by towing plankton net from 370 m. depth to sea-surface. During 18.34–19.10 DSL again appeared and ascended gradually in the range from the west off Sirane-Bank (bottom 60 m. depth) to Utubo-Ne Bank (bottom depth 19 m.), showing the lagged evening ascent (twilight 17.03–18.26).

10. Shrimp Fishing Ground in the Suruga Bay in Winter

On board of Seichō-Maru (62 ton) twelve members of our research group started the survey at 17.20 on 14. March, 1955 off Yaidu in the Suruga Bay from the oceanographic observation determined as the schedule (water temp. 15.0°–14.6°C in the upper layer above 100 m. depth), and submarine illumination.

At 17.50 (sunset) the fishing fleets (20 boats, 10 sets) left the Yaidu harbor and arrived to shrimp-fishing ground. (In this year unfavourable fishing continued from January and the day 14, Mar. was the first day after the lunar-vacation).

After we observed water temp. etc. (0–25 m. 15.0–14.9°C, 50–100 m. depth 14.6–14.7°C, 200 m. depth 13.7°C, 300 m 11.4°C) at 18.27 DSL separated from the sea-bottom (at 18.36, 126 m.) and began to ascend upward representing a black band of echo-trace (in the level depths 70–110 m.), showing the level 50–90 m. at 18.45 (bottom 150 m.), 0–80 m. level at 18.49 (bottom 165 m.), and at 18.55 arrived to the top-most layer and tended to diffuse the echo-trace of two echosounders (24 kc., 200 kc). We carried out the net towing (Y-type larval net designed by Messrs. Ihara and Yamaguchi) with speed 10 m/15 sec. during 1843–47 and obtained the harvest of small copepods, mythis, Sergestes 4, sagitta etc.

Next towing the plankton net from the level of 100 m. depth to 50 m depth and from 50 m. depth to sea-surface in two steps. We sampled those planktons and compared them to the above. As a consequence we recognized that the echo-trace by 200 kc. fish-finder indicates the special distinct one for shrimp shoal. We at once arranged the under-water television (British type), but were unsuccessful by some conditions.

During 19.03–19.15 the second towing of Y-type net in DSL. from 50 m, depth to 0 m. and brought the harvest of *Sergestes*-shrimps and copepods etc. At 19.17 DSL lied at the level of 15–45 m. depth, we towed the net in the layer of non-DSL (100 m–15 m. depth) and comparing the result of the above, we got about one half of the harvest (shrimps 2 and 1/2 vol. of copepods) where the bottom depth is about 360 m. At 20.34 the DSL suddenly faded away by unknown cause (supposingly due to the turning of tidal current or to the change of wind to north). On the morning of 15 Mar. at 05.05 DSL was found in the layer of 80–110 m. depth (bottom deeper than 360 m.) for the moon's altitude about 30°.

As a typical morning descent of DSL, it descended from the level depth of 100–130 m. at 05.20 to the depth of 160–180 m. at 05.30, to 190 m. depth at 05.40 (at last arrived to the sea-bottom, due to the drift of ship shallower than before), where the sea was homotherm above 100 m depth 14.6°C at 200 m depth 14.3°C, at 300 m, 11.3°C.

On the early morning of 16. Mar., we saw half moon in the sky, and several shrimp fishing boats on the sea.

At 05.52 sunset, we missed the morning descent of DSL, but we found the settled layer of DSL at 280 m depth at 06.30–06.45 in the upper one and the lower one at the level of 310–324 m. (bottom depth below 380 m, water temp. at 0–90 m, 14.6°–14.9°C, at 190 m 13.9°C, at 240 m. 11.3°C).

By the Y-type larval net sampling (hauled obliquely 28° up) from the level of 420 m to 280 m. depth during 06.50–06.55, we obtained rich zoo plankton (copepods etc.).

On the evening of 16 March, (sunset at 17.55 northwesterly strong wind disturbed our survey off C. Miho in Suruga Bay.

On the next morning 17 Mar., turning to calm weather, at 04.50 in the twilight off Miho (east of Simidu Harbor) a typical DSL appeared and indicated morning descent as follows:

Time h min.	Layers depth of DSL, (the upper one).	(the lower one)
05.28	60–80 m	220–250 m
05.50	0–85	210–245
05.58 (sunrise)	–	240–280 (bottom 340 m)
06.08	–	270–280–310 m (bottom 360 m)
06.16	–	280–300 m
08.00	–	325 m depth near hottom

(At 07.00 off Okitsu, 15.4–15.8°C above the 100 m. depth, 13.5°C at the 200 m depth, 10.9°C at the 300 m depth).

We towed the Y-type Net in the DSL appeared from 318 m depth to 250 m. depth and obtained rich macroplankton (and no *Sergestes*-shrimp). For comparison we towed also in the unfished layer of shrimp, similarly in the offing of Yui (bottom depth 350 m) at 08.00 a DSL (mingled with spotty fish-trace) appeared at the level of 40–70 m depth.

On evening 17 Mar., we tried again to investigate of the ascending state of DSL and obtained the results as follows:

Time	DSL layer depth	Bottom depth
17.45	210–240 m	290 m
17.50	220–240	310
17.56 (sun-set)	200–220	270
18.00	200	250
18.02	180–210	250
18.05	180–210	240
18.07	170–190	220
18.09	160–190	220

Since the ship drifted to the shallower region by the wind SSW (4) and the current during 17.45–18.08 ENE. 0.7 knot, 18.10 coming back to the first position, we observed again the continued evening ascent as follows:

Time	DSL	Bottom depth
18.21	120–150 m	320 m
18.26	120–140	360 m
18.28	100–130	
18.30	90–130	
18.32	80–125	
18.36	70–100	
18.40	60–100 (Y-type Net 160→70 m ∠40° hauled)	
18.43	40– 80	
18.51	40– 80	
18.51	30– 70	
18.53	20– 70	19.00 70→30 m. (Y-type Net) 19.11 80→0 m. macro-plankton (Copepods abundant) mixed with Sergestes-shrimp (which distinguished by DSL for 24 kc. and 200 kc. fish-detectors.)

The evening ascent of DSL during twilight from the 200 m depth at 17.50 to 60 m depth at 18.50 shows the comparatively speedy rate of ascent i.e. 2.89 m/min≒4.8 cm/s.

In this case the echo-trace of a fish-shoal (*Sergestes*-shrimp?) was detected by the 200 kc. fish-detector, however, the actual scatterer by net towing did not caught in the upper layer above 20 m. depth except jelly-fish.

Since at 21.00 in the offing of Yui, the water temperature 16.6°C at 0 m., 15.1°C at 100 m., 13.5°C at 200 m., 11.1°C at 300 m., depth we can conclude that the ascent of DSL did not affected by the thermal stratification (16°–13°C) and consequently occurred in the range of the optimum temperature of *Sergestes*-shrimp and zoo-planktons constituting the scatterer.

The DSL after 21h splitted into 3 layers in the layer of 20–70 m, at 19.52 changing in one layer at the level of 40–70 m., finally at 20.20 all diffused away.

Hence the experiment to test the effect of fish-lamp illumination on this DSL was stopped. Also on 18, 19. Mar. unfortunately stormy weather interrupted the survey by means of underwater television etc.

Summary

Results obtained by our investigation during three yeays (1952–1955) are summarized as follows:

(1) DSL occurs frequently in the favourable fishing grounds corresponding to the upwelling areas under the influence of the prevailing wind (monsoon etc.) near on the shelf-edge steeply-inclined slope and on the zone of convergence (oceanic front and coastal front), and near fishing-banks or on the head of sea-valleys etc.

(2) Sometimes DSL related with thermocline was found, as a typical example in Beppu Bay.

(3) The vertical migration of scatterers or DSL in relation to the variation of submarine illumination can explain the morning and evening favourable catch of fisheries (sardine, mackerel, squid etc.) and fish-swarming.

(4) The settling depth in daytime lies at the deepest level of 300–400 m. depth, perhaps restricted by the stratification of water temperature (generally in the range of 10°–15°C).

Acknowledgement

The authors wish to state their thanks for the aids of crews of Umitaka-Maru, Seichō-Maru, Sitigōtei and Messrs. T. Hirano, K. Okubo, Y. Saito, Y. Morita and others.

Physical and Chemical Data

1st Cruise in 1952 (by Umitaka-Maru)

Depth m	Temp. °C	Cl ‰	σt	O_2 cc/L	P_2O_5 γ/L	SiO_2 γ/L	PH
St. 1; 34–08.4N, 137–14.9E; Aug. 21, 1952; 1810–1945; Air Temp. 27.0; Weather b–bc; Wind WSW 3; Sea 2; Swell 1; Depth—; Current 335°–2.1′; Transp. 17; Color of Sea 2:							
0	27.2	18.27	21.17	—	—	—	—
10	25.79	18.63	22.10	—	—	—	—
25	20.31	19.06	24.35	—	—	—	—
50	17.97	19.15	24.99	—	—	—	—
83	15.51	19.22	25.66	—	—	—	—
93	14.87	19.12	25.71	—	—	—	—
140	13.08	19.11	26.03	—	—	—	—
186	11.66	19.06	26.25	—	—	—	—
383	9.72	19.02	26.52	—	—	—	—
424	6.99	18.95	26.84	—	—	—	—
St. 2; 33–44N, 138–08E; Aug. 22, 1952; 0030–0220; Air Temp. 27.6; Weather b; Wind S 3.5; Sea 1; Swell 1; Depth—; Current 70°–1.5′; Transp.—; Color of Sea—:							
0	27.2	18.41	21.37	4.52	7.56	520	—
10	27.10	18.53	21.57	4.41	5.78	340	—
25	22.96	18.73	23.14	4.64	6.67	660	—
50	18.89	19.21	24.73	3.90	12.00	840	—
75	17.85	19.02	24.84	4.36	19.11	710	—
96	16.54	19.04	25.20	4.07	26.22	1100	—
144	13.22	19.10	25.98	3.28	36.00	1500	—
192	11.21	19.05	26.31	3.28	73.34	1900	—
318	7.94	19.07	26.87	2.71	—	—	—
474	5.63	18.95	27.02	3.28	102.69	4800	—
635	4.32	19.12	27.42	1.70	112.55	6000	—
St. 3; 33–24.5N, 138–54.3E; Aug. 22, 1952; 0515–0620; Air Temp. 28.9; Weather bc; Wind N 2; Sea 1; Swell 1; Depth—; Current 90°–2.8′; Transp. 35; Color of Sea 1:							
0	28.7	18.63	21.17	—	—	—	—
10	28.78	18.71	21.26	—	—	—	—
25	28.77	18.76	21.33	—	—	—	—
50	27.91	18.91	21.82	—	—	—	—
75	27.07	19.09	22.33	—	—	—	—

103	25.01	19.12	23.02	—	—	—	—
155	22.12	19.27	24.06	—	—	—	—
207	20.74	19.28	24.46	—	—	—	—
336	14.70	19.12	25.70	—	—	—	—
503	9.83	18.99	26.46	—	—	—	—
600	6.70	18.93	26.85	—	—	—	—

St. 4; 33-12.6N, 139-36.1E; Aug. 22, 1952; 0855-1015; Air Temp. 28.8; Weather b; Wind E 5; Sea 2; Swell 1; Depth—; Current 90°-1.5′; Transp. 30; Color of Sea 2:

0	29.2	18.82	21.24	—	—	—	—
10	28.92	18.82	21.36	—	—	—	—
25	27.89	19.00	21.94	—	—	—	—
50	26.11	19.06	22.59	—	—	—	—
75	24.64	19.21	23.24	—	—	—	—
108	23.54	19.23	23.60	—	—	—	—
162	21.35	19.26	24.26	—	—	—	—
216	19.50	19.25	24.74	—	—	—	—
388	16.12	19.21	25.45	—	—	—	—
583	11.62	19.02	26.19	—	—	—	—
777	6.04	18.92	26.92	—	—	—	—

St. 6; 33-31.2N, 131-51.5E; Aug. 23, 1952; 1640-1745; Air Temp. 29.3; Weather c; Wind W 8; Sea 3; Swell 4; Depth—; Current 74°-1.6′; Transp. 24; Color of Sea 2;

0	29.0	18.53	20.96	4.20	0.92	—	—
9	29.02	18.73	21.21	4.27	0.92	—	—
22	28.97	18.85	21.37	4.55	0.92	—	—
44	27.96	19.02	21.95	2.41	1.82	—	—
66	26.54	—	—	6.56	3.63	—	—
89	26.10	19.09	22.63	4.38	4.53	—	—
134	22.64	19.23	23.86	2.33	4.53	—	—
179	20.04	19.24	24.58	4.20	8.13	—	—
230	19.52	19.31	24.82	4.32	8.13	—	—

St. S1; 33-33.6N; 140-04.0E; Aug. 23, 1952; 2010-2050; Air Temp. 27.0; Weather bc; Wind N 6; Sea 4; Swell 1; Depth—; Current 73°-1.05′; Transp.—; Color of Sea—:

0	29.1	18.84	21.34	—	—	—	—
10	28.94	18.82	21.35	—	—	—	—
25	28.39	18.89	21.64	—	—	—	—
49	28.09	18.95	21.81	—	—	—	—
61	27.17	19.07	22.22	—	—	—	—
81	25.43	19.18	22.95	—	—	—	—
105	24.46	19.21	23.30	—	—	—	—

St. S2; 33-30.7N, 140-04.3E; Aug. 24, 1952; 0000-0100; Air Temp. 28.2; Weather C with fine rain; Wind W/N 7; Sea 3; Swell 2; Depth—; Current 132°-1.4′; Transp.—; Color of Sea—:

0	29.1	18.79	21.25	—	—	—	—
9	28.88	18.89	21.44	—	—	—	—
23	28.50	18.94	21.67	—	—	—	—
46	27.12	19.07	22.39	—	—	—	—
47	26.99	19.12	22.39	—	—	—	—
62	26.24	19.47	23.02	—	—	—	—
80	24.79	19.21	23.19	—	—	—	—

St. S3; 33-28.0N, 140-12.2E; Aug. 24, 1952; 0415-0600; Air Temp. 26.8; Weather bc; Wind W/N 1; Sea 3; Swell 3; Depth—; Current—; Transp.—; Color of Sea—:

0	28.7	18.92	21.57	—	—	—	—
10	27.04	19.05	22.29	—	—	—	—
25	25.72	19.13	22.80	—	—	—	—
50	23.20	19.21	23.67	—	—	—	—
72	25.21	19.14	22.96	—	—	—	—
95	23.24	19.21	23.65	—	—	—	—
124	21.92	19.21	24.00	—	—	—	—

St. S4; 33-27.2N, 140-12.0E; Aug. 24, 1952; 0620-0650; Air Temp. 28.0; Weather bc; Wind NE 3; Sea 2; Swell 3; Depth—; Current 330°-0.8′; Transp. 35; Color of Sea 1-2:

0	28.9	18.83	21.45	—	—	—	—
10	28.77	18.86	21.46	—	—	—	—
28	28.51	18.85	21.54	—	—	—	—
57	26.97	19.06	22.32	—	—	—	—
75	25.27	19.15	22.97	—	—	—	—

St. 7; 33-55.5N, 139-52.0E; Aug. 24, 1952; 1513-1600; Air Temp. 27.7; Weather c; Wind NE 4; Sea 1; Swell 1; Depth—, Current—, Transp. 29; Color of Sea 1-2:

0	29.3	—	—	—	—	—	8.6
10	29.10	18.75	21.18	—		—	—
25	29.07	18.82	21.31	—	—	—	—
50	27.90	18.96	21.88	—	—	—	—
75	27.04	19.10	22.35	—	—	—	—
96	23.29	19.24	23.68	—	—	—	—
144	21.54	19.24	24.18	—	—	—	—
193	20.32	19.17	24.32	—	—	—	—
348	14.11	19.12	25.83	—		—	—
522	8.63	19.02	26.70	—	—	—	—

St. 8; 34-11.9N, 139-52.7E; Aug. 24, 1952; 1730-1835; Air Temp. 27.9; Weather bc; Wind E/N 1; Sea 1-0; Swell 1; Depth—; Current 326°-1.6′; Transp. 29; Color of Sea 1-2:

0	29.1	18.76	21.22	4.21	6.33	350	8.6
10	29.05	18.82	21.37	4.22	3.63	210	8.5
25	29.03	18.76	21.28	4.17	4.53	340	8.4
50	27.98	19.07	22.01	4.27	8.13	510	8.4
75	26.32	19.12	22.61	4.11	10.84	630	8.4
103	24.12	19.12	23.28	4.11	12.63	840	8.5
154	20.13	19.17	24.47	3.89	16.24	880	8.4
205	16.78	19.16	25.29	3.89	28.86	900	8.3
375	10.84	19.02	26.33	3.19	63.51	2200	—
563	5.40	18.99	27.10	2.01	107.25	4100	—
751	4.07	19.02	27.30	1.54	121.69	5000	—

St. 9; 34-31.5N, 139-56.4E; Aug. 24, 1952; 2009-2127; Air Temp. 27.6; Weather b; Wind NE/N 1; Sea 3-0; Swell 1; Depth—; Current 75°-1.9′; Transp.—; Color of Sea—:

0	28.6	18.60	21.20	—	—	—	—
10	27.63	18.73	21.68	—	—	—	—
25	25.30	18.82	22.46	—	—	—	
50	22.32	19.12	23.79	—	—		—
75	21.32	19.13	24.09	—	—	—	—

94	16.82	19.15	25.27	—	—	—	—
141	14.68	19.12	25.71	—	—	—	—
188	13.47	19.09	25.92	—	—	—	—

St. 10; 34-49.8N, 139-54.0E; Aug. 24, 1952; 2310-2340; Air Temp. 26.7; Weather bc; Wind NE 4; Sea 0; Swell 2; Depth—; Current W/s-0.5′, Transp.—; Color of Sea—:

0	26.6	18.29	21.41	4.49	0.92	510	—
10	25.54	18.47	21.98	4.60	1.17	500	—
25	20.94	18.98	24.21	4.06	14.44	790	—
50	17.03	19.12	25.18	3.75	23.45	820	—
75	15.84	19.12	25.45	3.56	27.96	1100	—
100	14.53	19.10	25.72	3.40	28.41	1300	—
150	12.15	19.06	26.14	3.35	53.19	1600	—

St. 11; 35-27.3N, 140-49.8E; Aug. 25, 1952; 0457-0535; Air Temp. 24.9; Weather c; Wind SE 1; Sea 1; Swell E 3; Depth—; Current SE-1′; Transp. 13; Color of Sea 5:

0	23.6	18.53	22.63	4.93	2.73	290	—
10	21.03	18.63	23.49	5.04	1.82	440	—
25	17.91	18.74	24.43	5.21	6.33	780	—
50	15.34	18.68	24.95	5.32	11.74	820	—
75	14.04	18.73	25.29	5.20	14.44	1000	—

St. 12; 36-05.6N, 141-14.5E; Aug. 25, 1952; 0920-1013; Air Temp. 26.0; Weather o; Wind W/S 3; Sea 2; Swell 1-2; Depth—; Current 23°-1.2′; Transp. 19; Color of Sea 3:

0	25.8	18.77	22.28	—	—	—	8.3
10	24.99	18.77	22.55	—	—	—	—
25	20.04	18.93	24.15	—	—	—	—
50	15.74	19.12	25.48	—	—	—	—
75	13.48	18.99	25.77	—	—	—	—
100	13.09	19.06	25.86	—	—	—	8.0
150	11.34	19.05	26.29	—	—	—	8.0
201	9.80	18.99	26.47	—	—	—	7.9
400	3.36	18.82	27.09	—	—	—	7.6
606	3.16	18.82	27.11	—	—	—	7.5

St. 13; 36-46.0N, 141-28.5E; Aug. 25, 1952; 1402-1452; Air Temp. 26.4; Weather c; Wind SW 2; Sea 1-2; Depth—; Current—; Transp. 18; Color of Sea 3:

0	24.6	18.75	22.63	4.64	8.93	350	8.4
10	23.84	18.74	22.84	4.97	2.63	110	8.5
25	16.77	18.71	24.70	5.32	2.63	450	8.4
50	13.35	18.68	25.38	5.54	10.84	520	8.4
75	12.05	18.73	25.70	5.76	8.13	730	8.4
101	11.14	18.79	25.96	5.60	26.15	920	8.3
151	11.16	19.04	26.29	5.71	52.29	1800	8.0
202	6.96	18.74	26.54	3.11	47.78	1600	8.0
387	2.42	18.66	26.93	5.03	98.24	4200	7.6

St. 14; 37-12.8N, 141-37.0E; Aug. 25, 1952; 1755-1830; Air Temp. 24.9; Weather c; Wind SW 5; Sea 2; Swell 1; Depth—; Current 45°-0.8′; Transp. 15; Color of Sea 4:

0	22.8	18.14	22.33	—	—	—	8.3
9	21.93	18.17	22.62	—	—	—	8.3
24	20.02	18.40	23.45	—	—	—	8.3
48	12.12	18.70	25.64	—	—	—	8.4

72	11.36	18.74	25.95	—	—	—	8.4
99	10.16	18.78	26.11	—	—	—	—
148	8.79	18.80	26.36	—	—	—	—
198	6.49	18.68	26.52	—	—	—	—

St. 14′; 37-17.6N; 141-36.5E; Aug. 25, 1952; 1928-2026; Air Temp. 24.8; Weather bc; Wind SW/W 3; Sea 2; Swell 1; Depth—; Current—; Transp.—; Color of Sea—:

0	22.2	18.08	22.42	—	—	—	—
11	21.59	18.20	22.76	—	—	—	—
27	15.26	18.55	24.79	—	—	—	—
53	12.71	18.81	25.69	—	—	—	—
80	10.84	18.75	25.95	—	—	—	—

St. 15; 38-13.0N; 141-40.0E; Aug. 26, 1952; 0110-0258; Air Temp. 23.7; Weather b; Wind 2; Sea 0; Swell 1; Depth—; Current 135°-1.2′; Transp.—; Color of Sea—:

0	20.8	18.43	23.27	5.15	4.53	440	—
10	19.37	18.44	23.66	5.43	6.93	450	—
26	16.77	18.58	24.50	5.72	13.54	500	—
52	14.22	18.63	25.12	5.66	8.13	610	—
78	12.08	18.70	25.65	5.71	18.95	830	—
95	9.52	18.67	26.07	5.71	25.25	1000	—
125	8.70	18.68	26.21	5.66	36.97	1200	—

St. 16; 37-57.5N, 142-05.0E; Aug. 26, 1952; 0405-0525; Air Temp. 23.4; Weather bc; Wind SW/W 4; Sea 1-2; Swell 2; Depth—; Current 90°-2.5′; Transp. 16; Color of Sea 4:

0	21.6	18.39	22.99	5.09	0.92	440	—
10	17.81	18.46	24.08	5.54	0.92	400	—
28	15.18	18.59	24.86	5.88	2.73	490	—
56	13.69	18.65	25.26	5.60	13.54	710	—
83	11.86	18.69	25.68	5.71	22.55	780	—
97	10.15	18.69	25.99	5.66	24.35	1000	—
145	8.74	18.69	26.22	5.54	23.45	1100	—
193	7.96	18.69	26.37	5.55	43.27	2300	—
387	3.01	18.66	26.88	5.09	118.07	4200	—

St. 17; 37-38.9N, 142-33.9E; Aug. 26, 1952; 0740-0840; Air Temp. 23.8; Weather b; Wind SW/W; Sea 3; Swell 1-2; Depth—; Current—; Transp. 20; Color of Sea 3;

0	21.3	18.42	23.13	5.09	0.92	430	8.4
10	20.89	18.43	23.46	5.20	1.82	430	8.4
24	16.05	18.56	24.63	5.94	4.53	440	8.4
49	12.22	18.69	25.61	5.72	18.85	510	8.5
75	10.66	18.68	25.89	5.72	24.35	620	8.2
100	9.87	18.73	26.09	5.49	24.35	800	8.2
150	8.84	18.76	26.29	5.32	29.76	1200	8.1
184	7,79	18.79	26.50	4.80	56.78	1800	8.1
368	2.02	18.55	26.80	4.58	109.06	3200	7.7
552	2.60	18.74	27.02	2.38	114.46	5300	7.6

St. 18; 37-12.5N, 143-15.1E; Aug. 26, 1952; 1230-1329; Air Temp. 28.9; Weather b; Wind W 5; Sea 3-4; Swell 2; Depth—; Current—; Transp. 21.5; Color of Sea 3:

0	27.7	18.70	21.60	—	—	—	8.5
10	27.07	18.81	21.95	—	—	—	8.5
25	23.91	18.78	22.88	—	—	—	8.5

49	22.26	19.18	22.89	—	—	—	8.5
65	21.37	19.23	24.21	—	—	—	8.4
87	20.81	19.23	24.56	—	—	—	8.4
130	18.23	19.17	24.94	—	—	—	8.0
170	15.73	19.15	25.51	—	—	—	8.2
256	9.64	18.75	26.14	—	—	—	8.2

St. 19; 37-42.0N, 144-05.8E; Aug. 26, 1952; 1630-1738; Air Temp.—; Weather b; Wind W/S 5; Sea 2; Swell—: Depth—; Current—; Transp.—; Color of Sea—:

0	24.8	18.77	22.60	4.59	13.54	660	8.4
10	23.64	18.61	22.73	4.81	3.63	590	8.3
25	18.61	19.06	24.70	4.27	15.34	820	8.3
50	15.84	19.09	25.41	3.65	29.76	1100	8.4
81	14.02	19.08	25.79	3.60	36.07	1500	8.1
108	12.73	19.04	26.00	3.53	50.48	1700	8.0
162	9.96	18.87	26.27	3.08	66.70	2400	7.9
187	9.12	18.99	26.58	3.03	73.01	3100	7.9
374	6.33	18.93	26.90	2.41	76.44	4300	7.7
551	4.19	18.90	27.12	1.57	130.68	5700	7.6

St. 20; 38-12.0N, 144-20.0E; Aug. 26, 1952; 2040-2134; Air Temp. 25.6; Weather b; Wind W 10; Swell 3; Depth—; Current—; Transp.—; Color of Sea—:

0	23.9	19.10	23.38	4.68	8.23	630	—
10	23.81	18.98	23.17	4.79	5.43	610	—
26	18.72	18.78	24.28	4.76	6.33	650	—
49	15.90	18.78	24.96	3.81	22.55	1100	—
75	15.13	19.12	25.62	3.41	36.97	1300	—
100	13.58	19.08	25.88	3.79	42.37	1500	—
149	10.43	18.99	26.36	3.70	52.29	1900	—
178	9.52	18.96	26.47	3.13	62.20	2300	—
356	4.10	18.77	26.94	3.13	91.03	4400	—
534	3.22	18.87	27.18	1.35	141.49	6100	—

St. 21; 38-42.0N, 144-48.0E; Aug. 27, 1952; 0103-0211; Air Temp. 25.3; Weather b; Wind NW/W 5; Sea 3; Swell 1; Depth—; Current—; Transp.—; Color of Sea—:

0	23.3	18.41	22.50	4.48	12.63	930	—
10	23.28	18.51	22.69	4.82	8.13	1500	—
24	17.54	18.41	24.09	6.61	8.13	1500	—
47	11.55	18.73	25.80	6.05	21.65	1700	—
61	12.40	19.02	26.03	5.93	29.97	2100	—
88	11.01	19.02	26.30	3.59	68.41	3000	—
132	9.02	18.97	26.46	2.58	89.23	3600	—
143	9.13	18.91	26.46	3.81	103.65	3600	—
286	5.69	18.82	26.82	3.13	108.06	4000	—
428	4.27	18.86	27.03	2.13	117.09	4600	—

St. 22; 38-36.1N, 144-17.1E; Aug. 27, 1952; 0445-0600; Air Temp. 23.9; Weather b-c; Wind W/N 4; Sea 2; Swell 1; Depth—; Current 135°-1.8′; Transp. 15; Color of Sea 3:

0	22.5	18.52	22.93	—	—	—	—
10	22.49	18.53	22.94	—	—	—	—
25	17.36	19.05	24.96	—	—	—	—
50	12.01	18.88	25.91	—	—	—	—

75	10.55	18.88	26.19	—	—	—	—
100	10.31	18.96	26.32	—	—	—	—
150	7.64	18.80	26.54	—	—	—	—
195	2.68	18.52	26.71	—	—	—	—
390	4.63	18.84	26.98	—	—	—	—
584	3.41	18.88	27.16	—	—	—	—

St. 23; 38-30.0N, 143-41.0E; Aug. 27, 1952; 0920-1040; Air Temp. 25.1; Weather b; Wind NW 1; Sea 1; Swell 2; Depth—, Current—; Transp. 19; Color of Sea 2:

0	22.0	18.41	22.92	5.05	9.03	440	8.4
10	20.99	18.41	23.20	5.04	5.43	520	8.4
25	16.34	19.05	25.29	5.39	8.13	590	8.3
50	12.35	18.94	25.93	4.59	24.35	1800	8.3
75	14.60	18.86	25.49	4.82	25.98	2100	8.3
100	9.88	18.93	26.36	4.71	47.78	2600	8.1
150	6.33	18.72	26.54	4.81	92.83	3500	8.0
199	3.71	18.62	26.75	4.92	106.35	4000	7.8
398	4.47	18.86	26.99	2.30	136.09	6500	7.7
598	4.11	18.96	27.21	1.52	154.11	7300	7.5

St. 24; 38-25.5N, 142-48.0E; Aug. 27, 1952; 1611-1705; Air Temp. 25.3; Weather b; Wind S 1.5; Sea 1; Swell 1; Depth—; Current—; Transp. 21; Color of Sea 2:

0	23.4	18.33	22.43	—			8.4
10	21.32	18.45	23.23	—	—	—	8.4
25	11.71	18.62	25.61	—	—	—	8.4
50	7.40	18.67	26.39	—	—	—	8.2
76	5.51	18.58	26.50	—	—	—	8.0
101	3.97	18.54	26.60	—	—	—	8.0
152	2.58	18.52	26.72		—		7.8
200	2.09	18.56	26.81	—	—	—	7.6
401	2.93	18.76	27.03		—	—	7.6
601	3.24	18.91	27.13	—	—		7.5

St. 25; 38-21.5N, 142-11.4E; Aug. 27, 1952; 2000-2135; Air Temp. 24.1; Weather b; Wind SW 6; Sea 3; Swell 1; Depth—; Current 195°-1′, Transp.—; Color of Sea—:

0	22.4	18.30	22.66	4.77	9.03	1600	—
10	22.19	18.29	22.71	4.88	8.13	1600	—
25	17.42	18.43	24.12	5.78	12.63	1600	—
49	6.78	18.40	26.08	6.79	38.77	1800	—
75	6.69	18.57	26.34	5.84	47.78	2200	—
100	6.17	18.60	26.45	5.72	60.48	2800	—
150	3.61	18.52	26.62	5.72	80.22	3900	—
200	3.34	18.58	26.74	5.28	117.26	5100	—
401	2.50	18.86	27.21	2.80	132.48	8000	—

St. 26; 38-22.3N, 141-46.1E; Aug. 28, 1952; 0000-0038; Air Temp. 24.2; Weather b; Wind SW 5; Sea 1; Swell 1; Depth—; Current—; Transp—; Color of Sea—:

0	21.2	18.44	23.18	—	—	—	—
10	19.27	18.46	23.70	—	—	—	—
24	16.13	18.54	24.59	—	—	—	—
48	13.65	18.67	25.30	—	—	—	—
77	11.75	18.77	25.79	—	—	—	—

103	11.10	18.76	25.92	—	—	—	—
134	10.74	18.76	25.99	—	—	—	—

St. 27; 38-08.7N, 141-38.0E; Aug. 28, 1952; 0255-0355; Air Temp. 22.0; Weather b; Wind SW 4; Sea 1; Swell 1; Depth—; Current 225°-1.3′; Transp.—; Color of Sea—:

0	20.4	18.38	22.96	—	—	—	—
25	19.20	18.59	23.91	—	—	—	—
50	13.40	18.65	25.31	—	—	—	—
100	11.51	18.82	26.18	—	—	—	—
200	7.59	18.69	26.39	—	—	—	—

2nd Cruise in 1952. (by Umitaka-Maru)

Depth m	Temp. °C	Cl ‰	σ_t	O_2 cc/L

St. 1; 33-20.6N, 132-56.2E; Dec. 4, 1952; 1435-1537; Air Temp. 8.8; Weather c; Wind NW 3; Sea 4; Swell—; Depth—; Current S—; Transp. 12; Color of Sea 5:

0	18.9	18.68	24.11	5.20
10	19.14	18.68	24.05	5.18
25	19.14	18.67	24.03	5.42
44	19.19	18.68	24.04	5.11
74	19.20	18.10	23.24	5.08

St. 2; 33-18.7N, 131-43.3E; Dec. 4, 1952; 1730-1802; Air Temp. 8.2; Weather c; Wind NW 6; Sea 2; Swell—; Depth 46; Current—; Transp.—; Color of Sea—:

0	18.1	18.38	23.90	5.03
10	18.23	18.36	23.85	5.06
25	18.02	18.32	23.84	5.13
40	17.76	18.29	23.87	5.18

St. 3; 33-16.6N, 131-30.9E; Dec. 4, 1952; 2130-, Air Temp. 7.4; Weather r; Wind N 3; Sea 1; Swell—; Depth 40; Current—; Transp.—; Color of Sea—:

0	18.0	18.27	23.77	5.11
10	18.37	18.20	23.64	5.05
25	18.38	18.29	23.71	4.98
35	18.36	18.29	23.71	5.01

St. 3′; 33-16.6N, 131-30.9E; Dec. 5, 1952; 0450-; Air Temp. 5.1; Weather c; Wind N 3; Sea—; Swell—; Depth 40; Current—; Transp.—; Color of Sea—:

0	17.8	—	—	—

St. 3″; 33-16.5N, 131-33.5E; Dec. 5, 1952; 0735-0750; Air Temp. 7.2; Weather bc; Wind NW 3; Sea 2; Swell—; Depth—; Current—; Transp.—; Color of Sea 6:

0	17.8	—	—	—

St. 4; 33-16.6N, 131-31.2E; Dec. 5, 1952; 1646-1707; Air Temp. 8.2: Weather C; Wind N 2; Sea 1; Swell—; Depth 60; Current—; Transp. 9; Color of Sea 6-7:

0	18.0	18.30	23.81	5.26
10	18.21	18.29	23.74	5.20
25	18.21	18.29	23.74	5.16
50	18.25	18.31	23.76	5.05

St. 4″; 33-16.6N, 131-31.2E; Dec. 5, 1952; 2120-2137; Air Temp. 6.5; Weather b; Wind N 3; Sea 2; Swell—; Depth 60; Current S; Transp.—; Color of Sea—:

0	18.0	18.29	23.80	5.21
10	18.20	18.29	23.75	5.14
25	18.21	18.30	23.76	5.12
50	18.18	18.30	23.77	5.11

St. 4‴; 33-16.6N, 131-31.2E; Dec. 6, 1952; 0410-0514; Air Temp. 5.4; Weather c; Wind WNW 1; Sea 1; Swell—; Depth 60; Current—; Transp.—; Color of Sea—:

0	18.0	18.29	23.80	5.17
10	18.12	18.31	23.79	5.06
25	18.13	18.29	23.78	5.04
50	18.08	18.30	23.80	5.06

St. 5; 33-16.6N, 131-32.2E; Dec. 6, 1952; 1018-1300; Air Temp. 9.1; Weather c; Wind W 4; Sea 3; Swell—; Depth 72; Bottom M.; Current—; Transp. 8; Color of Sea 5-6:

0	17.8	18.30	23.86	5.27
5	17.89	18.30	23.82	5.16
10	18.03	18.31	23.82	5.07
15	18.03	18.29	23.79	5.05
20	17.99	18.28	23.79	4.87
25	17.95	18.32	23.85	5.12
30	17.99	18.36	23.90	5.10
40	17.97	18.32	23.85	5.15
50	17.92	18.36	23.91	5.13
59	17.93	18.37	23.92	5.16
64	15.96	18.45	24.49	0.08
67	12.85	18.49	25.20	0.03
69	12.11	18.56	25.44	0.03

St. 6; 33-18.2N, 131-39.1E; Dec. 7, 1952; 0910-0930; Air Temp. 9.2; Weather c; Wind NW 2; Sea 2; Swell—; Depth 55; Current—; Transp. 10; Color of Sea 6:

0	17.6	18.34	23.97	5.32
10	17.66	18.31	23.91	5.14
25	17.68	18.30	23.90	5.25
50	17.61	18.30	23.91	5.29

St. 7; 33-18.7N, 131-49.5E; Dec. 7, 1952; 1035-1050; Air Temp. 11.3; Weather c; Wind WNW 3; Swell—; Depth 53; Current—; Transp. 12; Color of Sea 5:

0	18.0	18.62	24.26	5.30
10	18.20	18.61	24.19	5.21
25	18.22	18.61	24.18	5.28
50	18.23	18.60	24.17	5.32

St. 8; 33-12.9N, 132-02.3E; Dec. 7, 1952; 1243-1303; Air Temp. 12.6; Weather c; Wind NW 4; Sea 4; Swell—; Depth 104; Current N—; Transp. 14; Color of Sea 4:

0	19.0	18.88	24.35	5.08
10	19.08	18.88	24.33	5.13
24	19.06	18.87	24.33	5.23
47	19.10	18.86	24.30	5.25
95	19.11	18.88	24.32	5.29

St. 9; 33-04.9N, 132-08.5E; Dec. 7, 1952; 1350-1410; Air Temp. 17.5; Weather c; Wind NW 5; Sea 4-5; Swell—; Current—; Depth 92; Transp. 15; Color of Sea 4:

0	19.7	19.07	24.44	5.06
10	19.86	19.07	24.40	4.99

24	19.83	19.07	24.41	4.94
47	19.91	19.09	24.41	4.89
80	19.91	19.08	24.40	4.91

St. 10; 32-57.7N, 132-14.5E; Dec. 7, 1952; 1502-1517; Air Temp. 12.4; Weather c; Wind NNW 5; Sea 5; Swell—; Depth 98; Transp. 15; Color of Sea 3-4:

0	20.5	19.14	24.50	5.06
9	20.76	19.14	24.28	5.04
22	20.73	19.14	24.29	5.07
44	20.73	19.15	24.30	5.03
84	19.60	19.17	24.61	4.43

St. 11; 32-51.3N; 132-26.0E; Dec. 7, 1952; 1623-1640; Air Temp. 12.4; Weather c; Wind NNW 5; Sea 5; Swell—; Depth 107; Transp. 15; Color of Sea 3-4:

0	20.5	19.17	24.36	5.12
8	20.70	19.17	24.31	4.94
21	20.64	19.16	24.31	4.89
42	19.90	19.12	24.46	4.93
84	19.60	19.11	24.52	5.05

St. 12; 33-53.5N, 132-38.1E; Dec. 7, 1952; 1748-1804; Air Temp. 11.2; Weather c; Wind NE 3; Sea 1; Depth 62; Transp.—; Color of Sea—:

0	19.4	19.15	24.63	5.25
10	19.56	19.16	24.60	5.20
25	19.64	19.15	24.57	5.14
50	19.63	19.11	24.51	5.20

St. 13; 32-41.9N, 132-25.4E; Dec. 8, 1952; 1810-1825; Air Temp. 10.8; Weather r; Wind—; Sea 6; Swell—; Depth 140; Transp.—; Color of Sea—:

0	22.6	19.23	23.87	4.83
9	22.85	19.23	23.80	4.77
23	22.72	19.24	23.84	4.89
47	22.82	19.22	23.79	4.68
93	20.86	19.26	24.40	4.21

St. 14; 32-34.0N, 132-59.6E; Dec. 8, 1952; 2130-2200; Air Temp. 12.4; Weather r; Wind—; Sea—; Depth 96; Current—; Transp.—; Color of Sea—:

0	23.0	19.24	23.77	4.85
10	23.49	19.23	23.61	4.90
24	23.36	19.24	23.67	4.70
48	23.26	19.24	23.69	4.76
95	19.40	19.29	24.81	4.33

St. 15: 32-46.4N, 133-07.4E; Dec. 9, 1952; 0025-0054; Air Temp. 11.8; Weather r; Wind NNE 5; Depth 130; Transp.—; Color of Sea—:

0	20.9	19.15	24.21	4.96
25	21.16	19.09	24.09	5.67
50	21.14	19.10	24.09	5.43
99	21.14	19.12	24.12	5.87
119	20.75	19.11	24.22	6.08

St. 16; 33-07.2N, 133-10.2E; Dec. 9, 1952; 0553-0710; Air Temp. 11.0; Weather r; Wind NE/E 4; Sea 3; Depth 970; Transp.—; Color of Sea—:

0	21.3	19.17	24.13	5.87
10	21.52	19.17	24.09	5.71

24	21.55	19.17	24.09	5.42
48	21.15	19.17	24.19	5.66
95	19.78	19.17	24.56	5.02
126	19.35	19.18	24.68	5.14
168	14.76	19.17	25.08	3.90
252	9.77	19.17	26.73	3.60

St. 17; 33–15.2N, 134–16.1E; Dec. 9, 1952; 1005–1040; Air Temp. 12.2; Weather c; Wind NE/E 5; Sea 4; Swell 3; Depth 990; Transp. 23; Color of Sea 3:

0	21.2	19.16	24.25	5.63
9	21.35	19.16	24.23	5.85
24	21.39	19.15	24.11	5.46
47	21.35	19.14	24.10	4.92
84	20.36	19.08	24.28	4.14
127	18.66	19.16	24.82	4.59
169	15.26	19.17	25.64	3.76
253	11.41	19.10	26.34	3.48

St. 19; 33–37.2N, 134–53.4E; Dec. 11, 1952; 1930–2025; Air Temp. 12.6; Weather c; Wind N/W 4; Sea 4; Swell—; Depth 800; Transp.—; Color of Sea—:

0	20.5	18.87	23.93	4.92
10	20.94	19.18	24.26	4.90
25	20.72	19.17	24.30	4.80
50	20.73	19.17	24.30	4.85
100	18.36	19.17	24.91	4.38
126	15.41	19.18	25.61	3.96
168	13.02	19.14	26.08	3.77
252	11.15	19.07	26.24	3.41

St. 20; 33–28.1N, 135–58.6E; Dec. 12, 1952; 0215–0303; Air Temp. 11.0; Weather b; Wind NNW 4; Sea 2; Swell—; Depth 350; Transp.—; Color of Sea—:

0	20.5	19.17	24.37	5.12
10	20.94	19.17	24.25	5.03
25	20.92	19.17	24.26	5.11
50	20.80	19.17	24.34	4.93
100	18.16	19.15	24.94	4.43
150	14.98	19.17	25.71	3.75
200	13.72	19.14	25.94	3.65
300	10.34	19.15	26.62	3.22

St. 21; 34–02.0N, 136–27.5E; Dec. 12, 1952; 0710–0755; Air Temp. 11.6; Weather b; Wind N/W 2; Sea 3; Swell 2; Depth 410; Transp. 25; Color of Sea 3:

0	19.1	19.15	24.79	5.21
10	19.37	19.15	24.65	4.88
25	19.27	19.15	24.66	4.90
50	19.10	19.11	24.64	4.94
100	17.57	19.13	25.07	4.42
149	14.95	19.16	25.71	3.78
198	12.64	19.09	26.11	3.67
297	11.29	19.06	26.30	3.21

St. 22; 34–18.3N, 137–05.6E; Dec. 12, 1952; 1150–1219; Air Temp. 11.6; Weather b; Wind NW/N 6; Sea 5; Swell 2; Depth 150; Transp. 23; Color of Sea 3:

0	18.7	19.10	24.70	5.23
8	18.76	19.08	24.69	5.10
21	18.81	19.11	24.71	5.04
42	18.76	19.10	24.71	4.98
83	18.71	19.07	24.68	5.04

St. 23; 34-21.6N, 137-44.0E; Dec. 12, 1952; 1520-1623; Air Temp. 12.2; Weather b; Wind NW 4; Sea 4; Swell 3; Depth—; Current 67°-1.5′; Transp. 22; Color of Sea 4:

0	18.6	19.14	24.81	5.22
10	18.67	19.14	24.80	5.06
24	18.67	19.13	24.78	5.06
49	18.20	19.07	24.82	5.08
97	17.93	19.05	24.87	5.08
112	17.94	19.07	24.89	4.92
147	15.98	19.17	25.49	3.90
224	12.05	19.07	26.15	3.46
270	10.68	19.07	26.43	3.29
337	8.83	19.01	26.65	2.95

St. 24; 34-21.8N, 138-19.4E; Dec. 12, 1952; 1938-2010; Air Temp. 12.2; Weather b; Wind NW 3; Sea 4; Swell—; Depth—; Transp.—; Color of Sea—:

0	18.7	19.15	24.80	5.04
10	18.78	19.17	24.81	5.09
24	18.80	19.14	24.76	5.06
48	18.81	19.15	24.76	5.07
96	16.84	19.17	25.29	4.04

St. 25; 34-15.5N, 138-44.3E; Dec. 12-13; 1952; 2240-0022; Air Temp. 12.4; Weather b; Wind ENE 4; Sea—; Swell—; Depth—; Transp.—; Color of Sea—:

0	20.1	19.24	24.57	5.17
10	20.26	19.22	24.50	5.00
25	20.24	19.16	24.42	4.95
50	19.01	19.16	24.73	5.05
100	18.67	19.12	24.76	5.00
128	17.59	19.19	25.14	4.29
170	13.78	19.11	25.88	3.75
255	11.17	19.07	26.32	3.37
340	8.25	19.00	26.73	2.62
442	6.68	18.97	26.91	2.51
530	7.74	19.02	26.83	2.68
706	5.01	19.04	27.22	1.72

St. 26; 34-20.7N, 139-02.5E; Dec. 13, 1952; 0217- 0245; Air Temp. 10.8; Weather b; Wind NE 4; Sea—; Swell—; Depth 120; Current 135°; Transp.—; Color of Sea—:

0	18.6	19.17	24.90	5.10
10	18.66	19.16	24.82	5.09
25	18.58	19.17	24.86	5.26
50	18.58	19.17	24.86	5.22
100	17.22	19.17	24.95	4.02

St. S; 34-27.2N, 139-10.8E; Dec. 13, 1952; 0345-; Air Temp. 15.5; Weather b; Wind NE 3; Sea 3; Swell 2; Depth—; Transp.—; Color of Sea—:

0	19.0	19.23	—	—

St. 27; 34–43.8N, 139–09.8E; Dec. 13, 1952; 0530–0700; Air Temp. 10.6; Weather b; Wind N/E 3; Sea 2; Swell 2; Depth—; Current none; Transp. 21; Color of Sea 3–4:

0	18.3	19.09	24.82	4.97
10	18.60	19.08	24.73	4.92
25	18.58	19.11	24.78	4.85
50	18.60	19.09	24.84	4.90
100	18.57	19.10	24.87	4.94
146	16.02	19.17	25.48	4.10
189	15.31	19.08	25.50	4.09
283	11.29	19.07	26.38	3.36
338	9.86	19.05	26.54	3.29

3rd Cruise in 1952 (by Umitaka-maru)

Depth m	Temp. °C	Cl ‰	σ_t	0_2 cc/L	P.H.

St. 1; 34–58N, 139–48E; Feb. 12, 1953; 0629–0808; Air Temp. 13.8; Weather b; Wind WSW 2; Sea 2–3; Swell WSW 2; Depth 600; Current NE–0.7′; Transp. 19; Color of Sea 3:

0	16.48	19.25	25.49	5.07	8.4
10	16.54	19.25	25.48	5.18	8.4
25	16.48	19.22	25.45	5.00	8.4
50	16.14	19.21	25.52	5.11	8.4
75	15.26	19.19	25.67	5.13	8.4
99	14.98	19.20	25.75	5.13	8.4
148	14.50	19.18	25.83	5.02	8.4
200	12.05	19.06	26.12	3.68	8.1
300	9.08	18.98	26.57	3.39	7.9

St. 2; 34–57N, 139–27E; Feb. 12, 1953; 0905–1045; Air Temp. 14.5; Weather b; Wind NW 2; Sea 2; Swell SW 2–3; Depth 1350; Current N½W–0.9′; Transp. 18; Color of Sea 2–3:

0	15.3	19.19	25.65	5.32	8.4
10	15.51	19.18	25.60	5.13	8.4
25	15.26	19.22	25.70	5.40	8.3
50	14.96	19.20	25.76	4.69	8.4
75	14.86	19.20	25.77	5.26	8.4
99	14.42	19.16	25.82	4.41	8.3
149	13.30	19.11	25.97	4.17	8.2
198	11.95	19.06	26.19	3.80	8.1
276	9.77	19.03	26.53	—	8.0
358	8.12	—	—	2.99	7.8
586	5.62	18.99	27.07	2.08	7.8
781	4.42	19.01	27.24	1.67	7.8
976	3.50	19.05	27.39	1.38	7.6

St. 3; 35–03.8N, 139–21.8E; Feb. 12, 1953; 1149–1345; Air Temp. 16.6; Weather b; Wind SW/S 2; Sea 1; Swell 2; Depth 1350; Current N30°W–1; Transp. 23; Color of Sea 2–3:

0	15.4	19.19	25.64	5.03	8.4
10	14.84	19.19	25.76	—	—
25	14.78	19.19	25.78	—	—
50	14.83	19.19	25.77	5.30	8.4
75	14.74	19.20	25.80	—	—

96	14.81	19.18	25.81	5.46	8.4
143	13.77	19.13	25.91	—	8.4
191	11.88	19.07	26.21	3.74	8.2
287	10.22	19.04	26.47	3.43	8.0
383	8.90	18.98	26.80	3.20	7.8
586	5.62	18.99	27.07	2.08	7.8
781	4.42	19.01	27.24	1.67	7.6
976	3.50	19.05	27.39	1.38	7.6

St. 4; 35-10.4N, 139-31.6E; Feb. 12, 1953; 1452-1526; Air Temp. 17.4; Weather b; Wind SE 2; Sea 1; Swell 1; Depth 210; Current—; Transp. 17; Color of Sea 3-4:

0	15.7	19.22	25.61	5.63	8.4
10	15.71	19.19	25.57	—	—
25	15.04	19.20	25.73	—	—
50	14.57	19.19	25.83	5.41	8.4
73	14.52	19.19	25.84	—	—
81	14.57	19.19	25.83	5.22	8.4
121	14.07	19.16	25.90	—	—
162	13.74	19.16	26.00	4.88	8.4

St. 5; 35-14.6N, 139-20.2E; Feb. 12, 1953; 1654-1740; Air Temp. 15.7; Weather b; Wind S 1-2; Sea 1-2; Swell 1; Depth 800; Transp. 12; Color of Sea 4:

0	14.9	19.18	25.73	5.50	8.4
10	14.61	19.19	25.82	—	—
25	14.58	19.16	25.79	—	—
50	14.62	19.16	25.78	5.34	—
74	14.48	19.16	25.80	—	—
98	14.16	19.16	25.87	4.73	8.4
149	13.33	19.16	26.04	—	—
194	12.61	19.07	26.06	3.91	8.3
298	9.86	19.01	26.48	—	—
393	7.54	18.98	26.80	2.80	7.8

St. 6; 35-12.4N, 139-13.4E; Feb. 12, 1953; 1826-1907; Air Temp. 13.8; Weather b; Wind S 2; Sea 1; Depth 900; Current—; Transp.—; Color of Sea—:

0	14.7	19.19	25.80	5.44	—
10	14.73	19.19	25.79	—	—
25	14.65	19.19	25.81	—	—
50	14.65	19.18	25.81	5.23	—
74	14.51	19.17	25.82	—	—
99	13.91	19.15	25.91	4.36	—
148	13.83	19.14	25.91	—	—
196	12.08	19.06	26.15	5.36	—
295	10.54	19.04	26.42	—	—
393	8.08	18.97	26.71	2.88	—

St. 7; 35-03.1N, 139-11.8E; Feb. 13, 1953; 0945-1015; Air Temp. 10.8; Weather o; Wind NE 4; Sea 2; Swell 1-2; Depth 370; Current—; Transp. 15; Color of Sea 4:

0	14.6	19.23	25.88	5.30	8.4
10	14.73	19.19	25.79	—	—
25	14.75	19.18	25.77	—	—
50	14.63	19.19	25.81	5.08	8.4

74	14.54	19.17	25.81	—	—
96	14.77	19.12	25.69	5.00	8.4
144	13.49	19.18	26.04	—	—
192	12.30	19.06	26.11	3.70	8.2

St. 8; 34–53.3N, 139–14.2E; Feb. 13, 1953; 1130–1212; Air Temp. 11.3; Weather o; Wind N 3; Sea 3; Swell 1–2; Depth 1150; Current—; Transp. 17; Color of Sea 3–4:

0	14.5	19.21	25.87	5.67	8.4
10	14.64	19.18	25.79	—	—
25	14.72	19.19	25.79	—	—
50	14.66	19.19	25.31	5.26	8.4
75	14.72	19.19	25.16	—	—
98	14.66	19.19	25.36	5.20	8.4
147	13.11	19.12	25.97	—	—
191	12.13	19.17	26.29	3.64	8.2
287	10.02	19.01	26.45	—	—
383	8.82	18.99	26.92	3.06	8.0

St. 9; 34–44.1N, 139–07.8E; Feb. 13, 1953; 1315–1400; Air Temp. 11.9; Weather c; Wind NNE 4–5; Sea 3; Swell S 2; Depth 550; Current S; Transp. 15; Color of Sea 3:

0	14.5	19.20	25.85	5.44	8.5
10	14.67	19.20	25.82	—	—
25	14.72	19.24	25.86	—	—
49	14.63	19.21	25.84	5.46	8.4
71	14.53	19.19	25.83	—	—
95	14.22	19.16	25.86	4.66	8.4
142	13.44	19.14	26.00	—	—
166	13.15	19.10	26.00	4.02	8.3
249	11.52	19.07	26.27	—	—
332	9.35	18.99	26.54	3.19	8.0

St. 10; 34–34.5N, 139–02.5E; Feb. 14, 1953; 1808–1845; Air Temp. 9.0; Weather c; Wind NE 4; Sea 3–4; Swell—; Depth 420; Current—; Transp.—; Color of Sea—:

0	15.3	19.19	25.68	5.42	—
10	15.46	19.22	25.66	—	—
25	15.22	19.19	25.67	—	—
49	14.85	19.18	25.75	5.15	—
74	14.57	19.17	25.81	—	—
99	14.26	19.17	25.87	5.24	—
148	14.00	19.16	25.91	—	—
197	12.51	19.16	26.22	4.00	—
300	9.47	19.03	26.58	3.28	—

St. 11; 34–34.6N, 138–40.2E; Feb. 14, 1953; 2040–2134; Air Temp. 9.5; Weather bc; Wind E 3; Sea 3; Swell—; Depth 1110; Current 310°–0.84′; Transp.—; Color of Sea—:

0	16.0	19.25	25.60	4.09
10	16.05	19.23	25.56	—
25	16.05	19.23	25.57	—
50	15.00	19.18	25.72	4.55
75	14.84	19.18	25.75	—
100	14.61	19.16	25.78	4.45
149	13.85	19.16	25.94	—

185	12.87	19.12	26.08	4.13	
278	10.82	19.06	26.39	—	
371	9.26	19.02	26.60	3.21	

St. 12; 34-42.2N, 138-41.2E; Feb. 14, 1953; 2210-2316; Air Temp. 9.8; Weather c; Wind NW-W 3; Sea 1; Depth 380; Current 10°-0.41′; Transp.—; Color of Sea—:

0	16.1	19.22	25.53	5.52	—
10	16.27	19.23	25.51	—	—
25	16.22	19.24	25.53	—	—
50	16.10	19.23	25.56	5.06	—
75	14.85	19.19	25.77	—	—
100	14.48	19.19	25.85	5.11	—
150	14.27	19.19	25.89	—	—
200	13.69	19.16	25.98	4.57	—
300	11.08	19.06	26.35	3.53	—

St. 13; 34-52.8N, 138-42.3E; Feb. 15, 1953; 0015-0125; Air Temp. 10.8; Weather b; Wind SSW-W 4; Sea 4; Depth 560; Current 23°-1.8′; Transp.—; Color of Sea—:

0	15.5	19.20	25.63	5.50	—
10	15.71	19.22	25.71	—	—
26	15.23	19.23	25.73	—	—
50	14.50	19.18	25.83	5.30	—
58	14.20	19.18	25.89	—	—
78	14.15	19.17	25.87	5.24	—
116	14.06	19.19	25.94	—	—
137	14.00	19.19	25.95	5.27	—
205	13.81	19.16	25.95	—	—
273	10.92	19.06	26.37	3.49	—

St. 14; 34-53.3N, 138-34.8E; Feb. 15, 1953; 0210-0315; Air Temp. 8.4; Weather b; Wind NW/W 2; Sea 1-2; Swell 1; Depth 840; Current—; Transp.—; Color of Sea—:

0	13.6	19.18	26.02	5.54	—
10	13.81	19.16	25.95	—	—
25	13.88	19.16	25.93	—	—
50	13.87	19.17	25.95	4.97	—
74	13.80	19.16	25.95	—	—
99	13.71	19.16	25.97	5.29	—
148	13.45	19.16	26.02	—	—
197	12.16	19.07	26.14	3.67	—
296	10.58	19.06	26.45	—	—
390	8.88	19.03	26.69	2.94	—

St. 15; 35-04.7N, 138-36.6E; Feb. 15, 1953; 0423-0533; Air Temp. 8.0; Weather b; Wind NNW 2; Sea 2; Swell 1; Depth 600; Transp.—; Color of Sea—:

0	12.8	18.30	24.91	5.57	—
10	13.66	19.07	25.85	—	—
25	13.85	19.16	25.94	—	—
50	13.90	19.16	25.94	5.10	—
74	13.93	19.16	25.93	—	—
99	13.85	19.16	25.94	5.22	—
148	13.79	19.16	26.00	—	—
190	13.35	19.14	26.02	4.68	—
285	11.23	19.06	26.32	—	—
380	9.56	19.03	26.57	3.05	—

St. 16; 35-05.2N, 138-46.8E; Feb. 15, 1953; 0625-0711; Air Temp.—; Weather b; Wind NNW 2; Sea 1; Swell 1; Depth 570; Transp. 17; Color of Sea 4:

0	13.9	19.17	25.94	5.39	—
10	14.05	19.18	25.92	—	—
25	13.97	19.15	25.90	—	—
50	13.95	19.16	25.92	5.30	—
74	13.95	19.16	25.92	—	—
99	14.00	19.16	25.91	5.45	—
149	14.02	19.16	25.91	—	—
200	13.77	19.16	25.95	5.22	—
300	11.39	19.05	26.28	—	—
400	9.97	19.02	26.58	3.19	—

St. 17; 35-00.0N, 138-39.1E; Feb. 15, 1953; 0800-1025; Air Temp. 11.9; Weather b; Wind NW/W 1; Sea 1; Swell 2-3; Depth 1300; Current 285°-0.35′; Transp. 28; Color of Sea 3:

0	13.9	19.18	25.95	5.33	8.4
10	13.82	19.17	25.96	—	—
25	13.99	19.16	25.91	—	—
50	13.91	19.16	25.92	5.28	8.4
75	13.90	19.14	25.90	—	—
100	13.83	19.16	25.94	4.34	8.4
150	13.77	19.16	25.96	—	—
200	13.55	19.16	26.00	5.11	8.4
300	10.90	19.04	26.35	—	8.2
400	9.04	19.00	26.70	2.71	8.0
600	6.10	18.99	27.01	2.21	7.8
797	4.64	19.01	27.22	2.00	7.8
996	3.82	19.05	27.37	1.87	7.6

St. 18; 34-51.3N, 138-23.5E; Feb. 17, 1953; 0743-0828; Air Temp. 6.8; Weather bc; Wind SW/W 6; Sea 4-5; Swell 2; Depth 690; Current W-0.5′; Transp. 13; Color of Sea 3-4:

0	13.5	19.16	26.01	5.11	8.4
10	13.72	19.15	25.95	—	—
25	13.67	19.14	25.95	—	—
50	13.65	19.14	25.95	5.35	8.4
67	13.70	19.14	25.94	—	—
89	13.76	19.16	25.96	5.25	8.4
134	13.71	19.16	25.97	—	—
135	13.72	19.16	25.97	5.08	8.4
183	10.86	19.05	26.37	—	8.3
366	8.86	19.00	26.63	2.98	8.2

St. 19; 34-46.3N, 138-33.2E; Feb. 17, 1953; 0921-1000; Air Temp. 8.1; Weather c; Wind W 6; Sea 5; Swell S 3; Depth 520; Current 77°-0.75′; Transp. 19; Color of Sea 2-3:

0	14.1	19.16	25.91	5.08	8.4
10	14.09	19.16	25.89	—	—
25	14.09	19.16	25.89	—	—
50	14.03	19.16	25.90	4.99	8.4
67	13.69	19.16	25.97	—	—
89	13.70	19.16	25.97	3.62	8.2
134	12.18	19.07	26.14	—	—
175	11.91	19.06	26.34	3.62	8.2

263	10.54	19.04	26.42	—	—
350	9.28	19.01	26.58	3.10	8.0

St. 20; 34-39.3N, 138-21.7E; Feb. 17, 1953; 1122-1207; Air Temp. 8.8; Weather b; Wind W 6; Sea 5; Swell 3; Depth 430; Current W; Transp. 16; Color of Sea 3:

0	13.5	19.15	26.00	5.49	8.4
8	13.63	19.15	25.97	—	—
21	13.61	19.16	26.00	—	—
43	13.63	19.15	25.97	5.36	8.4
64	13.63	19.16	25.99	—	—
85	13.75	19.16	26.00	5.18	8.4
127	13.41	19.16	26.03	—	—
170	13.37	19.16	26.04	4.78	8.4
254	11.29	19.06	26.04	3.46	8.2
301	10:43	19.04	26.44	3.31	8.0

St. 21; 34-34.7N, 138-29.1E; Feb. 17, 1953; 1250-1335; Air Temp. 9.0; Weather c; Wind W 5-6; Sea 5; Swell WSW 4; Depth 1370; Current E-2.3′; Transp. 12; Color of Sea 3:

0	14.2	19.16	25.85	5.36	8.4
10	14.35	19.16	25.88	—	—
25	14.25	19.16	25.86	—	—
50	13.75	19.16	25.95	4.75	8.4
58	13.71	19.16	25.97	—	—
78	13.59	19.16	26.00	5.27	8.4
117	13.57	19.16	26.00	—	—
139	13.60	19.15	25.98	4.64	8.4
209	12.09	19.07	26.18	—	—
279	9.97	19.09	26.58	3.31	—

St. 22; 34-26.2N, 138-48.8E; Eeb. 17, 1953; 1510-1550; Air Temp. 10.4; Weather c; Wind W 6; Sea 6; Swell W 5; Depth 880; Current ENE-4.2′; Transp. 15; Color of Sea 3:

0	16.7	19.24	25.42	5.41	8.5
9	16.90	19.22	25.44	—	—
23	16.89	19.28	25.44	—	—
46	16.39	19.21	25.47	5.18	8.4
56	16.07	19.21	25.53	5.19	8.4
86	14.67	19.20	25.52	—	—
130	14.86	19.18	25.75	5.03	8.4
194	13.31	19.11	25.97	—	—
259	10.38	19.02	26.43	3.46	8.2

St. 23; 34-21.5N, 139-02.3E; Feb. 17, 1953; 1653-1705; Air Temp. 10.3; Weather c; Wind W 8; Sea 6-7; Swell 5; Depth 360; Current—; Transp. 13; Color of Sea 3-4:

0	17.9	19.26	25.15	5.23	8.4
9	17.98	19.25	25.12	—	—
22	17.99	19.26	25.15	—	—
43	17.84	19.24	25.14	5.14	8.4
85	16.98	19.20	25.30	4.80	8.4

St. 24; 34-22.3N, 139-20.0E; Feb. 17, 1953; 1850-1918; Air Temp. 9.9; Weather c; Wind NNW 9-10; Sea 4; Swell—; Depth 110; Current—; Transp.—; Color of Sea—:

0	16.2	19.24	25.54	5.08	—
8	16.22	19.25	25.55	—	—

20	16.21	19.20	25.49	—	—
40	16.24	19.20	25.49	5.15	—
61	16.14	19.21	25.52	5.07	—

St. 25; 34–44.0N, 139–30.1E; Feb. 17, 1953; 2210–2253; Air Temp. 9.3; Weather bc; Wind WSW 4–5; Sea 4; Swell—; Depth 1.200; Current 75°–1.05′; Transp.—; Color of Sea—:

0	14.6	19.17	25.84	5.13	
10	14.66	19.17	25.78	—	—
25	14.73	19.24	25.87	—	—
50	14.64	19.22	25.86	5.04	—
73	14.74	19.17	25.76	—	—
97	14.67	19.17	25.78	5.04	—
146	13.22	19.12	26.00	—	—
173	13.22	19.11	25.99	4.30	—
259	12.06	19.07	26.18	—	—
345	9.07	18.98	26.57	3.16	—

St. 26; 34–34.2N, 139–26.1E; Feb. 19, 1953; 2000–2030; Air Temp. 9.5; Weather b; Wind SSW 1; Sea 1; Swell 3; Depth 94; Current 144°–1.4′; Transp.—; Color of Sea—:

0	16.5	19.26	25.50	5.42	—
10	16.55	19.23	25.54	—	—
24	16.49	19.22	25.44	—	—
48	16.52	19.24	25.47	5.14	—
82	15.41	19.17	25.61	5.08	—

St. 27; 35–08.2N, 140–25.0E; Feb. 20, 1953; 0155–0220; Air Temp. 6.8; Weather b; Wind NE 3; Sea 3; Swell—; Depth 46; Current—; Transp.—; Color of Sea—:

0	13.9	19.21	25.99	5.37	—
10	13.61	19.18	26.02	—	—
25	13.13	19.12	26.01	—	—
32	12.86	19.11	26.09	4.29	—

St. 28; 35–03.6N, 140–10.8E; Feb. 20, 1953; 0550–0537; Air Temp. 5.7; Weather b; Wind N 4; Sea 3; Depth 490; Current S–1′; Transp.—; Color of Sea—:

0	13.8	19.17	25.96	5.36	—
10	13.85	19.23	26.03	—	—
24	13.85	19.16	25.94	—	—
48	12.44	19.08	26.11	4.03	—
72	11.90	19.07	26.35	—	—
97	10.47	19.02	26.46	3.62	—
141	9.91	18.99	26.44	—	—
188	9.53	18.99	26.51	3.45	—

1st Cruise in 1953 (by Seichō-Maru)

Depth m	Temp. °C	Cl ‰	σ_t	O_2 cc/L	O_2/O_2' %

St. 1; 35–00.2N, 139–49.6E; Oct. 25, 1953; 0517–0620; Air Temp. 27.3; Weather b; Wind 0,0; Sea 0–1; Swell 0; Depth 29; Transp. 8; Color of Sea—:

0	22.4	18.70	23.22	—	—

10	22.64	18.69	23.13	4.81	93
25	22.62	18.69	23.14	4.77	93

St. 2; 35–00.6N, 139–48.6E; Oct. 25, 1953; 0415–0945; Air Temp. 20.5; Weather b; Wind—; Sea—; Swell—; Depth 70; Transp. 14; Color of sea—:

0	22.4	18.73	23.25	5.03	97
10	22.53	18.69	23.16	5.04	97
25	22.17	18.68	23.25	4.85	93
50	19.96	18.89	24.13	4.43	82
64	18.35	19.08	24.79	4.23	77
99	16.66	19.09	25.22	3.99	70

St. 2′; 35–00.7N, 139–48.2E; Oct. 25, 1953; 1050–1118; Air Temp. 21.3; Weather b; Wind—; Sea 3; Swell—; Depth—; Transp. 16; Color of Sea—:

0	22.4	18.75	23.28	5.01	97
36	21.16	18.78	23.66	4.71	89
135	15.03	19.09	25.58	4.01	69
180	13.48	19.09	25.92	3.70	61

St. 3; 35–01.2N, 139–48.5E; Oct. 25, 1953; 1600–1636; Air Temp. 20.8; Weather b; Wind NE 4; Sea 3; Swell 3; Depth 40: Transp. 12.5; Color of Sea—:

0	22.1	18.75	23.36	5.12	98
10	22.20	18.67	23.22	4.72	91
20	22.00	18.68	23.29	5.13	98
40	18.99	18.97	24.24	4.23	78

St. 4; 35–00.8N, 139–46.8E; Oct. 25, 1953; 1730–1851; Air Temp. 20.0; Weather b; Wind ESE 3; Sea 2; Swell 0; Depth 118; Transp.—; Color of Sea—:

0	21.9	18.71	23.36	5.09	96
10	22.04	18.73	23.34	5.17	99
25	22.06	18.68	23.27	4.96	95
50	21.78	18.70	23.38	4.23	81
75	18.14	19.00	24.74	4.33	78
100	17.20	19.07	35.06	4.05	72

St. 5; S 1.2 miles off Ashika-Zima (Tōkyo Bay); Oct. 26, 1953; 1245–1400; Air Temp. 18.2; Wind N 4; Sea 3; Swell—; Depth—; Transp. 9; Color of Sea 5–6;

0	19.9	—	—	5.26	—
9	19.94	—	—	5.16	—
18	19.87	—	—	4.88	—
35	19.89	—	—	4.75	—
53	18.91	—	—	4.23	—
73	17.99	—	—	3.87	—

2nd Cruise in 1953 (by Seichō-Maru)

Depth m	Temp. °C	Cl ‰	*σtr*	P.H.

St. 1; 34–51.4N, 138–21.6E—34–51.3N, 138–20.1E; Mar. 12, 1954; 1825–1917; Air Temp. 10. 3; Weather b; Wind W 4; Sea 1–2; Depth–; Transp.—; Color of Sea—:

0	15.1	18.62	24.92	8.4
10	15.86	19.10	25.41	8.3
25	12.06	19.20	26.34	8.4
40	15.80	19.12	25.46	8.4

St. 3; 34-51.4N, 138-20.9E—34-50.9N, 138-21.9E; Mar. 13, 1954; 0530-0630; Air Temp. 4.1; Weather bc; Wind W3-4; Sea 2; Swell 1; Depth over 370; Transp. 4; Color of Sea 5:

0	15.2	19.03	25.46	8.4
10	15.74	19.11	25.45	8.4
25	15.94	19.13	25.43	8.4
50	15.76	19.12	25.47	8.4
100	15.64	19.16	25.55	8.4
145	13.85	19.12	25.88	8.3
193	10.78	19.09	26.44	8.3

St. 4; 34-51.1N, 138-21.2E; Mar. 13, 1954; 1700-1800; Air Temp. 10.0; Weather bc; Wind W4; Sea-; Swell-; Depth 200; Transp. 3; Color of Sea 7;

0	16.1	18.91	25.11	8.4
10	16.61	19.14	25.31	8.4
25	16.38	19.15	25.38	8.4
49	16.19	19.20	25.48	8.4
99	15.87	19.17	25.51	8.4
148	12.84	19.16	26.09	8.3

St. 6; 34-51.2N, 138-21.5E—34-50.7N, 138-22.5E; Mar. 14, 1954; 1545-1640; Air Temp. 9.6; Weather b; Wind SSW 3; Sea 3; Swell, -; Depth 240; Transp. 3; Color of Sea 6:

0	15.6	18.73	24.94	8.4
10	16.46	19.11	25.30	8.4
25	16.45	19.20	25.43	8.4
50	16.47	19.19	25.41	8.4
99	15.46	19.12	25.54	8.4
148	14.00	19.14	25.88	8.3
198	11.09	19.05	26.33	8.3

St. 8; 35-00.1N, 138-32.9E—34-59.0N, 138-32.9E; Mar. 14, 1954; 2350-0020; Air Temp. 6.5; Weather b; Wind W 1; Sea 1; Swell-; Depth 220; Transp-; Color of Sea 8:

0	15.7	18.73	25.08	8.4
10	16.16	19.12	25.39	8.4
25	15.92	19.17	25.50	8.4
50	15.81	19.18	25.52	8.4
99	15.53	19.14	25.54	8.4
149	13.49	19.20	26.03	8.3
198	12.47	19.11	26.15	8.3

St. 9; 35-03.5N, 138-36.0E—35-03.2N, 138-36.0E; Mar. 15, 1954; 1128-1143; Air Temp. 10.4; Wind SE/S 1; Sea 1; Swell-; Depth 400; Transp. 3.6; Color of Sea 6:

0	15.9	18.50	24.58	8.5
10	16.47	19.11	25.30	8.4
49	16.35	19.19	25.44	8.4
99	14.95	19.16	25.70	8.4

St. 10; 35-05.4N, 138-40.6E—35-05.2N, 138-41.0E; Mar. 15, 1954; 1230-1245; Air Temp. 11.1; Wind SSW 1; Weather b; Sea 1-2; Swell 1; Depth 498; Transp. 6.5; Color of Sea 6:

0	16.1	18.84	25.03	8.4
10	16.70	19.20	25.36	8.4
49	16.44	19.23	25.47	8.4
99	15.05	19.13	25.64	8.4

St. 11; 35-07.4N, 138-44.4E—35-07.3N, 138-45.0E; Mar. 15, 1954; 1320-1347; Air Temp. 12.0; Weather b; Wind S 1; Sea 1; Swell—; Depth 200; Transp. 3; Color of Sea 7:

0	16.0	18.66	24.78	8.4
10	16.20	19.01	25.23	8.4
50	17.73	19.16	25.53	8.4
100	14.07	19.12	25.84	8.4

St. 12; 35-07.5N, 138-42.0E; Mar. 15, 1954; 1400- —, Air Temp. 12.9; Weather b; Wind S 1; Sea 1; Swell 1; Depth 175; Transp. 3; Color of Sea 10:

0	17.0	18.15	23.85	8.4
10	16.56	19.11	25.28	8.4
50	15.94	19.18	25.51	8.3
100	14.51	19.11	25.73	8.3
150	12.66	19.09	26.08	8.2

St. 13; 35-06.5N, 138-40.0E; Mar. 15, 1954; 1450- —, Air Temp. 12.8; Weather b; Wind SE 2-3; Sea 2-3; Swell 1; Depth 180; Transp. 1; Color of Sea 8:

0	16.1	16.80	22.21	8.4
10	16.51	19.07	25.23	8.4
50	15.71	19.15	25.52	8.4
99	14.36	19.14	25.81	8.3
149	12.55	19.17	26.22	8.2

St. 14; 35-06.2N, 138-37.8E; Mar. 15, 1954; 1540-1600; Air Temp. 12.5, Weather b; Wind NE 2; Sea 2; Swell 2; Depth-; Transp. 3; Color of Sea 7:

0	14.8	14.51	19.43	8.4
5	16.38	18.25	24.52	8.5
10	16.08	19.21	25.53	8.4
25	16.68	19.21	25.39	8.4
50	16.30	18.40	24.36	8.4

St. 15; 35-05.0N, 138-34.3E; Mar. 15, 1954; 1630-1650; Air Temp. 12.9; Weather b; Wind N 2; Sea 2; Swell 2-3; Depth 250; Transp. 3; Color of Sea 6:

0	15.9	18.28	24.27	8.4
10	16.17	18.95	25.15	8.4
50	16.08	19.20	25.51	8.4
100	14.30	19.15	25.83	8.3
200	11.89	19.09	26.22	8.2

St. 16; 35-03.5N, 138-33.1E; Mar. 15, 1954; 1730- —; Air Temp. 12.8; Weather b; Wind NNW 1; Sea 2; Swell S 3; Depth 110; Transp. 3.2; Color of Sea 6:

0	15.2	17.92	23.95	8.5
10	16.04	18.87	25.06	8.4
25	16.51	19.20	25.40	8.4
50	15.93	19.18	25.50	8.4
100	14.61	19.13	25.73	8.3

St. 17; 34–59.1N, 139–07.4E; Mar. 17, 1954; 1550–1610; Air Temp. 12.9; Weather b; Wind ENE 1; Sea 1; Swell ENE 2; Depth 75; Transp. 14; Color of Sea 4;

0	15.8	19.21	25.58	8.4
10	15.73	19.20	25.57	8.4
25	15.64	19.20	25.60	8.4
50	15.29	19.18	25.64	8.4
70	14.72	19.15	25.74	8.4

St. 18; 35–03.6N, 139–06.8E; Mar. 17, 1954; 1715– —; Air Temp. 11.6; Weather bc; Wind ENE 1; Sea 1; Swell 2; Depth 200; Transp. 14; Color of Sea 4:

0	15.7	19.22	25.61	8.4
10	15.66	19.18	25.56	8.4
25	15.54	19.20	25.64	8.4
50	15.51	19.19	25.62	8.4
100	13.68	19.12	25.92	8.3
150	12.28	19.09	26.20	8.2

St. 19; 35–04.1N, 139–05.8E; Mar. 17, 1954; 1940– —, Air Temp. 10.6; Weather c; Wind –; Sea 1; Swell –; Depth 95; Transp. –; Color of Sea –:

0	15.5	19.21	25.65	—
10	15.54	19.19	25.56	—
25	15.54	19.20	25.61	—
50	15.54	19.10	25.49	—
75	14.93	19.24	25.81	—
90	14.43	19.09	25.72	—

St. 20; 35–04.0N, 139–06.2E—35–04.4N, 139–06.2E; Mar. 18, 1954; 0430–0525; Air Temp. 9.8; Weather c; Wind ENE 3; Sea 3; Swell 2; Current 85°–0.4′; Depth –; Transp. –; Color of Sea—:

0	15.3	19.24	25.72	—
10	15.61	19.19	25.59	—
25	15.68	19.20	25.59	—
50	15.59	19.20	25.60	—
75	14.66	19.13	25.73	—
99	14.17	19.11	25.90	—

St. 21; 35–04.3N, 139–07.4E—35–04.0N, 139–07.2E; Mar. 18, 1954; 0540–0605; Air Temp. 9.7; Weather c; Wind NE/E—; Sea 3; Swell 2; Depth 295; Transp. 13; Color of Sea 4:

0	15.4	19.20	25.65	8.4
10	15.57	19.18	25.59	8.4
25	15.55	19.18	25.59	8.4
50	15.57	19.18	25.59	8.4
99	14.55	19.11	25.72	8.4
147	12.52	19.08	26.09	8.3
196	11.57	19.05	26.24	8.3
293	9.04	19.00	26.60	—

St. 22; 34–58.9N, 139–09.2E—34–57.3N, 139–09.4E; Mar. 18, 1954; 1612–1750; Air Temp. 11.4; Weather c; Wind NNE 1; Sea 0; Swell 2; Current 150°—0.4′; Depth 150; Transp. 15; Color of Sea 4:

0	15.2	19.18	25.66	8.4
10	15.33	19.15	25.59	8.4

25	15.48	19.20	25.63	8.4
50	15.44	19.20	25.64	8.4
75	14.84	19.13	25.69	8.4
100	14.18	19.11	25.80	8.3
130	13.05	19.08	26.00	8.3

1st Cruise in 1954 (by Umitaka-Maru)

Depth m	Temp. °C	Cl ‰	σ_t	0_2 cc/L	$0_2/0_2'$ %	P r/L	Si mg/L
St. 1; 35-00.9N, 139-17.1E,—35-00.2N 139-47.2E; Oct. 17, 1954; 0515-0826; Air Temp. 16.9; Weather b; Wind NNE 3-4; Transp. 14; Color of Sea 4; Sea 3; Depth 364:							
0	22.4	18.71	23.23	4.92	95	7.5	0.5
10	22.71	18.71	23.13	4.97	96	6.3	0.4
24	22.72	18.72	23.15	4.93	96	5.7	0.5
48	21.02	18.91	23.87	4.40	83	13.2	0.6
96	18.47	19.06	24.74	4.14	75	19.9	0.5
144	14.33	19.10	25.76	3.90	66	18.2	0.6
192	14.21	19.08	25.76	3.79	64	25.9	0.7
246	12.27	19.05	26.10	3.52	58	31.1	0.8
296	10.13	19.02	26.44	3.11	48	37.5	1.1
345	8.97	19.01	26.63	2.78	42	46.3	1.1
St. 2; 35-00.15N, 139-42.36E—34-59.84N, 139-47.95E; Oct. 17, 1954; 1627-1720; Air Temp. 20.0; Weather c; Wind NNE, 3; Transp. 13; Color of Sea 4; Sea 2; Depth 290:							
0	22.6	18.75	23.22	4.87	94	5.8	0.5
10	23.70	18.75	22.90	4.93	97	4.2	0.4
25	22.71	18.74	23.17	4.86	94	6.4	0.3
50	19.70	19.02	24.37	4.12	76	14.3	0.4
99	16.16	19.11	25.37	3.98	69	22.7	0.6
148	14.85	18.75	25.16	3.82	65	28.2	0.7
198	13.70	19.06	25.83	3.68	61	27.5	0.4
St. 3; 35-01.56N, 139-48.05E—35-00.89N, 139-48.33E; Oct. 17, 1954; 1915-1939; Air Temp. 19.3; Weather c-r; Wind NNE 5; Transp.-; Color of Sea -; Sea 3; Depth 70-80:							
0	22.2	18.79	23.39	5.09	98	8.8	0.4
10	22.44	19.10	23.74	4.87	95	10.8	0.7
25	22.33	18.77	23.32	4.85	94	7.3	0.5
50	22.33	18.78	23.34	4.76	92	13.8	0.5
St. 4; 35-01.12N, 139-48.58E—34-59.91N, 139-48.46E; Oct. 18, 1954; 1622-1725; Air Temp. 16.0; Weather r; Wind N 5; Tramsp. 13; Color of Sea 3-4; Sea 4; Current S 42°W-0.34′:							
0	22.0	18.75	23.38	4.94	95	6.4	0.4
10	22.36	18.74	23.27	4.88	94	3.5	0.4
25	22.24	18.74	23.30	4.97	96	4.9	0.5
50	18.63	19.06	24.70	4.50	82	12.7	0.6
72	17.13	19.08	25.09	3.91	69	17.6	0.5
97	16.60	19.10	25.25	3.95	69	20.8	0.5
St. 5; 35-01.35N, 139-48.90E—35-01.30N, 139-48.93E; Oct. 18, 1954; 1938-1947; Air Temp. 15.8; Weather -; Wind -; Transp. -; Color of Sea -; Depth-:							
0	22.2	18.74	23.32	4.95	95	8.5	0.5
10	22.30	18.74	23.33	4.98	96	7.7	0.6
25	22.11	18.80	23.42	4.67	90	11.6	0.6

St. 6; 35-01.13N, 139-47.72E—35-00.95N, 139-47.37E; Oct. 18, 1954; 2005-2027:

0	22.2	18.80	23.40	4.87	94	8.6	0.5
25	22.31	18.75	23.30	4.88	94	5.5	0.5
50	21.75	18.82	23.56	4.58	88	11.1	0.4
74	18.36	19.09	24.77	4.06	73	14.3	0.5

St. 7; 35-00.45N, 139-48.86E—34-59.98N, 139-48.76E; Oct. 19, 1954; 0540-0625; Wind N 4-5; Current S18°W-0.9′:

0	22.2	18.75	23.33	4.92	94	8.0	0.5
10	22.16	18.75	23.34	4.83	93	8.2	0.4
25	22.09	18.80	23.43	4.82	93	10.9	0.3
48	20.67	18.95	24.01	4.32	81	14.3	0.5
72	19.66	19.03	24.40	4.26	79	14.5	0.7
96	19.33	19.03	24.48	4.13	76	18.4	0.5

St. 8; 35-00.34N, 139-46.84E—34-59.37N, 139-46.50E; Oct. 19, 1954; 0718-0810; Air Temp. 16.7; Weather c; Wind N 6; Transp. 15; Color of Sea 4; Sea 5; Depth 250:

0	22.0	18.75	23.38	4.92	94	5.6	0.6
24	22.23	18.75	23.37	4.90	94	7.7	0.5
48	21.97	18.82	23.49	4.73	91	10.0	0.4
97	19.66	19.00	24.35	4.24	79	12.8	0.5
124	16.64	19.09	25.33	4.02	71	20.8	0.6
166	13.93	19.10	25.83	3.71	62	27.1	0.7
249	10.83	19.04	26.37	3.27	52	35.4	1.2

St. 9; 35-01.00N, 139-47.80E—35-00.10N, 139-47.54E; Oct. 19, 1954; 1525-1607; Air Temp. 19.2; Weather bc; Wind N 4; Transp. 13; Color of Sea 3; Sea 3; Swell 2; Depth 230; Current S42°W-0.33′:

0	22.0	18.77	23.41	4.89	94	—	—
10	22.04	18.75	23.37	4.91	94	—	—
22	21.98	18.79	23.45	4.78	92	—	—
43	19.50	19.05	24.47	4.14	76	—	—
64	18.67	19.05	24.67	4.12	75	—	—
86	18.16	19.08	24.84	4.07	73	—	—
171	15.14	19.10	25.57	3.83	66	—	—

St. 12; 35-00.69N, 139-49.22E—35-00.47N, 139-49.21E; Oct. 19, 1954; 1710-1723; Air Temp. 16.5; Weather bc; Wind NNE 4; Sea 3; Swell 2:

0	21.8	18.77	23.47	4.92	94	—	—
10	22.08	18.74	23.34	4.91	94	—	—
25	22.11	18.82	23.44	4.58	88	—	—

St 13; 35-00.53N, 139-47.78E—34-59.90N, 139-47.52E; Oct. 19, 1954; 1749-1835; Air Temp. 17.5; Wind NNE 5; Sea 5; Swell 2; Depth 270:

0	21.8	18.80	23.51	4.98	95	—	—
10	21.98	18.77	23.41	5.08	98	—	—
25	21.93	18.77	23.43	4.75	91	—	—
49	19.20	19.07	24.57	4.18	77	—	—
67	18.64	19.06	24.68	4.09	74	—	—
88	18.30	19.06	24.78	4.00	72	—	—
177	14.73	19.08	25.64	3.78	66	—	—

2nd Cruise in 1954 (by Seichō-Maru)

Depth m	Temp. °C	Cl ‰	σ_t	O_2 cc/L	O_2/O_2' %
St. 1; 34–51.3N, 138–21.4E; March 14, 1955; 1723–1736; Air Temp. 12.3; Weather b; Wind NE 2; Transp. 6; Color of Sea 5; Current N–1.0′; Depth 34:					
0	15.0	19.16	25.70	5.69	97
10	14.77	19.16	25.76	5.10	87
25	14.58	19.16	25.80	4.44	75
St. 2; 34–51.8N, 138–23.2E; March 14, 1955; 1820–1954; Air Temp. 9.4; Weather b; Wind WSW 2; Sea 2; Current 60°–0.9′; Depth 350:					
0	14.9	19.17	25.75	5.57	95
10	15.01	19.16	25.70	5.85	100
25	14.92	19.16	25.71	5.47	93
50	14.70	19.15	25.77	5.51	94
94	14.64	19.15	25.78	5.41	92
188	13.69	19.11	25.91	—	—
282	11.43	19.08	26.31	4.03	64
St. 3; 34–50.1N, 138–20.2E; March 15, 1955; 0530–0600; Air Temp. 10.5; Weather o; Wind N 2; Sea 2; Depth 360:					
0	14.5	19.15	25.80	5.63	95
10	14.61	19.13	25.76	5.57	95
25	14.65	19.15	25.78	5.48	93
50	14.64	19.14	25.76	5.58	95
100	14.58	19.14	25.78	5.68	96
197	14.30	19.15	25.83	5.17	87
295	11.30	19.06	26.31	3.77	60
St. 4; 34–50.4N, 138–22.0E; March 16, 1955; 0519–0547; Air Temp. 8.4; Weather bc; Wind NE 2; Transp. 4; Color of Sea 5; Current N80°W–1.0′; Sea 1; Swell 1; Depth 295:					
0	14.6	18.96	25.50	5.95	101
10	14.73	18.96	25.49	5.76	98
25	14.80	19.03	25.56	5.65	96
50	14.90	19.16	25.72	5.54	95
90	14.76	19.15	25.74	5.50	94
187	13.85	19.13	25.90	4.75	80
235	11.81	19.06	26.20	3.77	61
St. 5; 35–01.5N, 138–30.8E; March 16, 1955; 1745–1750; Air Temp. 13.8; Weather bc; Wind SSW 4; Transp. 6; Sea 3–4; Depth 12:					
0	14.9	18.57	25.68	5.67	96
5	14.96	18.57	25.66	5.60	95
10	15.32	19.02	25.42	5.70	98
St. 6; 35–02.9N, 138–33.6E; March 17, 1955; 0637–0701; Air Temp. 12.7; Weather b; Wind N 2; Transp. 10; Sea 2; Swell 2; Current SSW–0.3′; Depth 340:					
0	15.6	19.13	25.52	5.72	99
10	15.79	19.14	25.49	5.63	98
25	15.64	19.14	25.53	5.62	97
50	15.50	19.14	25.56	5.47	94

96	15.43	19.17	25.61	5.44	94
193	13.52	19.13	25.98	4.42	74
290	10.89	19.13	26.33	3.58	57

St. 7; 35–02.6N, 138–34.0E; March 17, 1955; 2100–2125; Air Temp. 16.8; Weather b; Wind SW 3; Sea 3; Swell 3; Depth 340:

0	16.6	18.94	25.02	5.77	101
10	16.20	19.16	25.42	5.66	99
25	15.99	19.16	25.48	5.66	97
50	15.57	19.16	25.57	5.67	98
99	15.11	19.16	25.68	5.70	98
198	13.53	19.12	25.96	4.72	79
297	11.05	19.04	26.32	3.47	55